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TECHNOLOGY REVIEW

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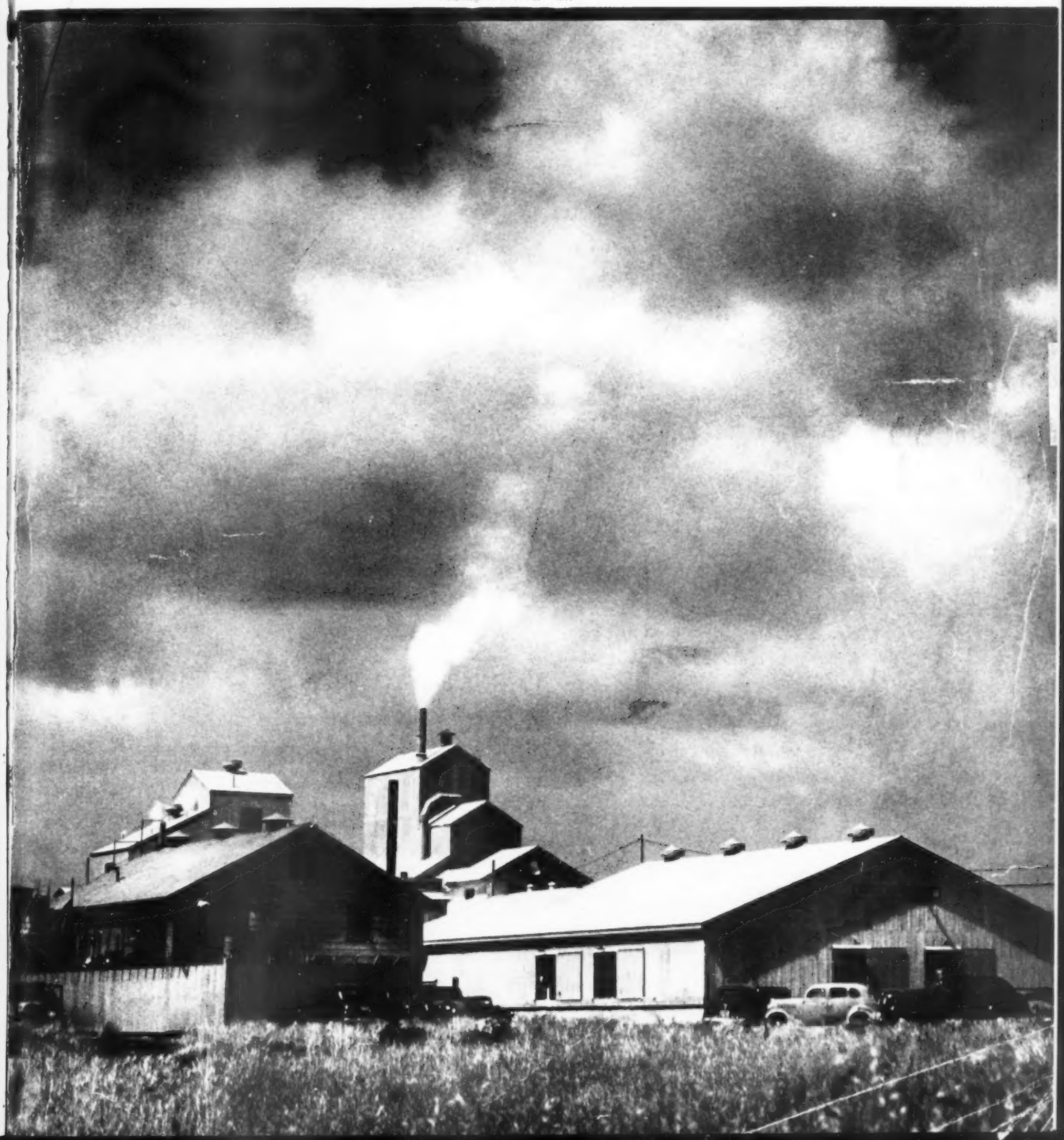
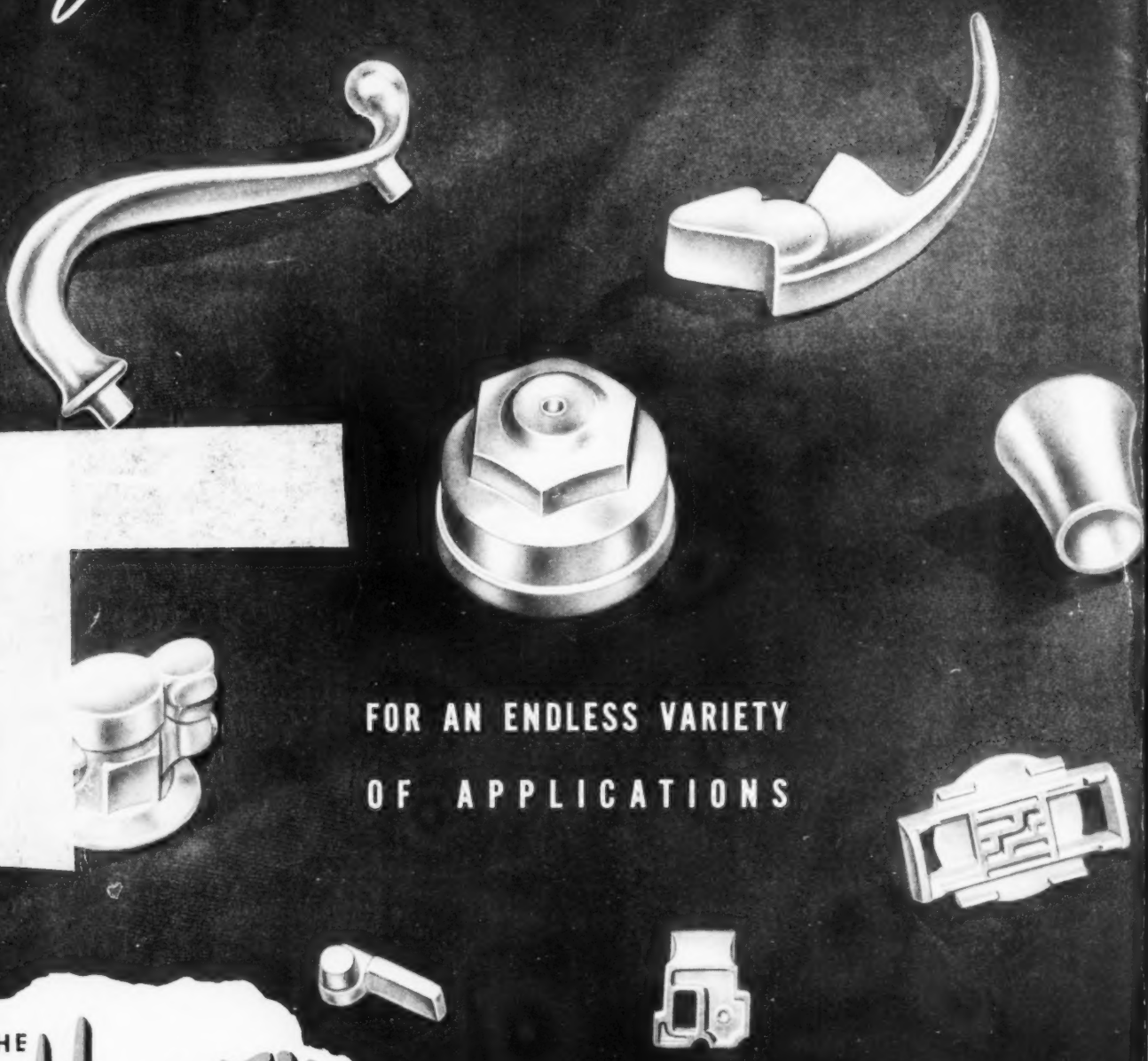


NON-FERROUS FORGINGS

for STRENGTH · LESS MACHINING · FEWER REJECTS



FOR AN ENDLESS VARIETY
OF APPLICATIONS

THE HARVEY METAL CORPORATION

HAROLD B. HARVEY '05 • *Engineers & Manufacturers* • SHERRY O'BRIEN '17

74th STREET and ASHLAND AVENUE • CHICAGO 36, ILLINOIS

FORGINGS IN ALUMINUM • BRASS • BRONZE • COPPER • MAGNESIUM • MONEL • ALLOYS

MACHINING FACILITIES

TS

YS

Bookkeeping records seldom show the *true costs* of eye accidents—merely compensation and medical expense. However, the "hidden" costs* (machinery and work damage, idle time and lowered worker morale, to name but a few) are estimated—by a recognized authority—to be *four times* the amount of the direct cost of eye accidents.

Why not let your nearest A-O Safety Representative show you how much an adequate eye-protection program can save for you.

*Not Insurable

American Optical Company
Safety Division

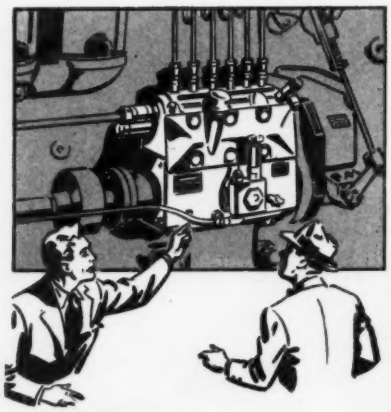
SOUTHBRIDGE, MASSACHUSETTS
BRANCHES IN PRINCIPAL INDUSTRIAL CITIES

Send for a copy of the latest study of Eye Accident Costs.

THE TECHNOLOGY REVIEW, November, 1946. Vol. XLIX, No. 1. Published monthly from November to July inclusive at 10 Ferry Street, Concord, N. H. Publication date: twenty-seventh of the month preceding date of issue. Annual subscription $3.50; Canadian and Foreign subscription $4.00. Entered as second-class matter at the Post Office at Concord, N. H., under the Act of March 3, 1879.

GOOD FUEL INJECTION

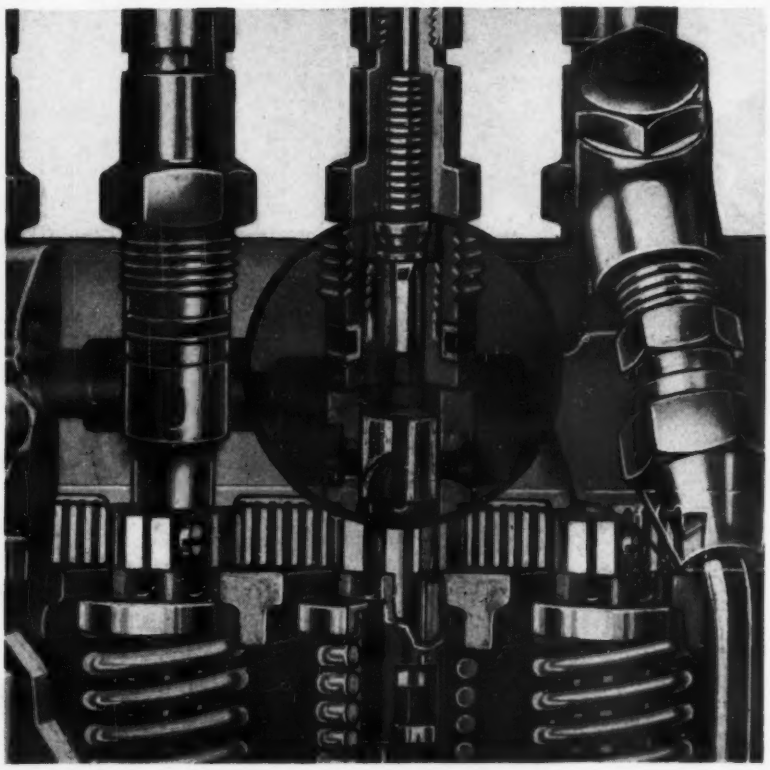
Pays Dividends



"DIVIDENDS?"
"Yes — from better engine performance and lower operation and maintenance costs over long service cycles. That explains why American Bosch Fuel Injection is known the world over as '*good* fuel injection'."

●

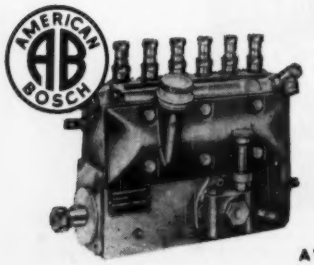
"WHAT MAKES the system good? Accumulated 'know-how' and leadership throughout the years — 'know-how' that follows through even in the smallest part. Here, for example is just one tiny but vital part — the delivery valve. It must be designed and held to exacting tolerances to perform the dual key functions of preventing excessive draining of fuel oil from the line system and controlling the pressure remaining in the system, from pump to nozzle valve, between injection strokes."



"YOU'LL FIND the same values in all other parts of American Bosch Fuel Injection Systems. Yes, *good* fuel injection pays dividends and goes right on paying them."

WRITE FOR A COMPLETE DIRECTORY OF AMERICAN BOSCH AUTHORIZED SERVICE STATIONS

AMERICAN BOSCH CORPORATION, SPRINGFIELD 7, MASS.



AMERICAN BOSCH

Diesel Fuel Injection

AVIATION AND AUTOMOTIVE ELECTRICAL PRODUCTS • FUEL INJECTION EQUIPMENT

Already a Sensation—
32 Alundum Grinding Wheels

INTRODUCED only a month ago, the new 32 ALUNDUM Grinding Wheels are already making truly sensational records. *And there are definite reasons.*

32 ALUNDUM Wheels are Sharper

By a patented Norton electric furnace process the grains of "32" form as single crystals of correct size — each one with a nubbly surface and many sharp points. And there's no crushing operation to produce flat surfaces. When the grains of 32 ALUNDUM abrasive are bonded into a wheel there are always many sharp points exposed.

There's More Usable Abrasive in 32 ALUNDUM Wheels

32 ALUNDUM abrasive is over 99% pure fused alumina—no slag—no pores. You not only get *more* sharp cutting points in a 32 ALUNDUM wheel but points that don't dull easily because they're all *usable* abrasive.

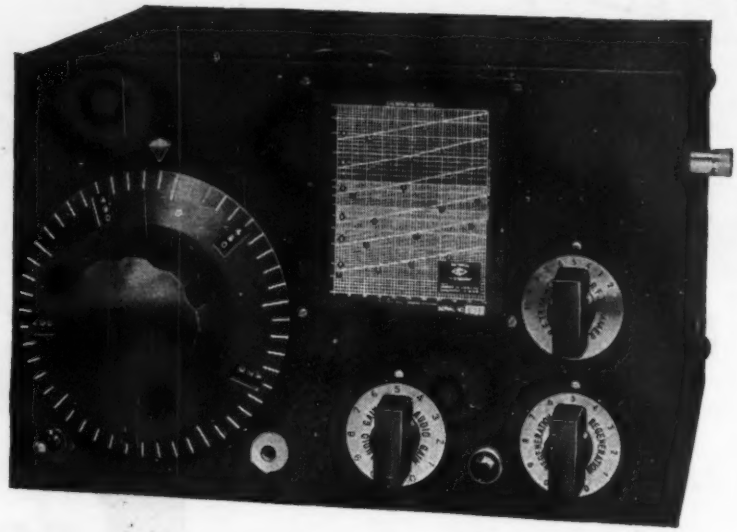
Ask your Norton abrasive engineer to give you a Vectograph demonstration of the new 32 ALUNDUM abrasive.

NORTON COMPANY, WORCESTER 6, MASS.

Distributors in All Principal Cities

W-1078

NORTON ABRASIVES



THE 1-10A

The ONE-TEN-A is a complete redesign of the ONE-TEN, retaining all the proven design features of the older model but with improved performance and smoothness of control.

For many years the ONE-TEN has been the "standard" receiver for work in the range from one to ten meters. Although many advances in high frequency technique have been made since this little receiver was first introduced, it has easily held its place in the affections of experienced amateurs by its consistent dependability under actual operating conditions and its high usable sensitivity.

The new ONE-TEN-A inherits the fine qualities of its predecessor brought up to date by a complete restudy of circuit, mechanical arrangement and constructional details.

The ONE-TEN-A is a fine receiver.

These furnaces are a long way from a tire maker's plant, yet they are an important part of the rubber industry. They're at Ville Platte, Louisiana, and they are making carbon black to add toughness and mileage to the nation's truck and automobile tires.

But Ville Platte's carbon black represents only a part of Cabot production. From the pine timber country of Florida, to the alfalfa fields of the Rio Grande valley and the natural gas fields of Texas, Oklahoma and West Virginia, Cabot Companies are at work providing essential raw materials for American industry.

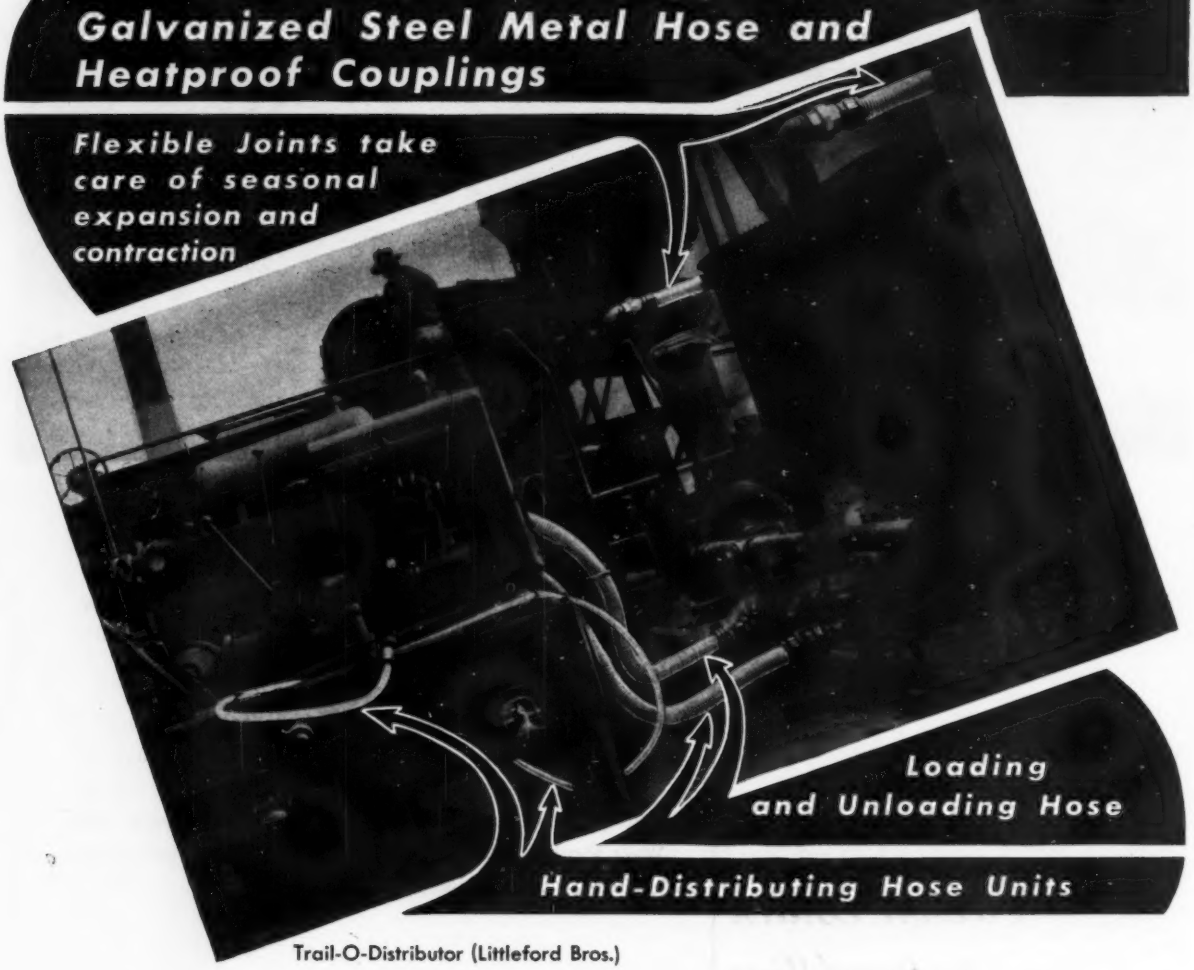
Carbon Black
Natural Gas
Natural Gasoline
Pumping Equipment
Pine Tar
Charcoal
Carotene
Chlorophyl

CABOT CARBON CO.
TEXAS ELF CARBON CO.
GENERAL ATLAS CARBON CO.
CABOT SHOPS, INC.
VALLEY VITAMINS, INC.

CABOT

GODFREY L. CABOT, INC.
77 FRANKLIN STREET · BOSTON 10, MASS.

Transfer Pump Unit equipped with PENFLEX Galvanized Steel Metal Hose and Heatproof Couplings


Flexible Joints take care of seasonal expansion and contraction
Loading and Unloading Hose
Hand-Distributing Hose Units

Trail-O-Distributor (Littleford Bros.)

This mobile transfer pump unit for use with storage tanks is equipped with two lengths of PENFLEX Unloading Hose which give large capacity and PENFLEX Hand-Distributing Lines which, if needed, have added value for redistribution.

A unit of this type equipped with the PENFLEX Expansion Joints and Heatproof Couplings, on the storage tanks, suggests the wide variety of industrial uses to which PENFLEX Products can be put.

The four-wall interlocked PENFLEX construction is extremely flexible, reduces parts breakage, resists thermal and mechanical strains and absorbs vibration. Heatproof Couplings are furnished.

Our engineers have had a vast amount of experience in almost every conceivable application of flexible tubing and hose. They will be glad to discuss your problems with you. PENFLEX Products are listed in trade catalogs and directories for your convenience — *for detailed information, write our Engineering Department.*

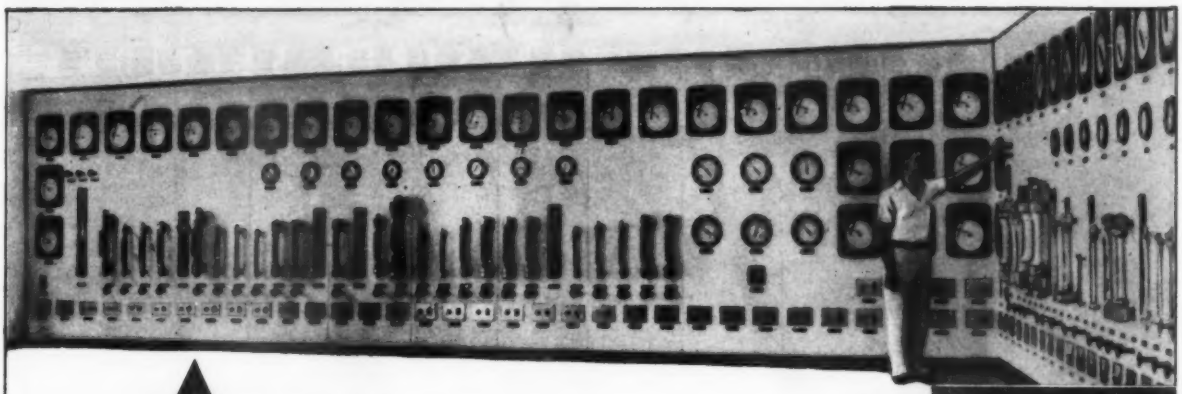
PENFLEX SALES COMPANY

DIVISION OF

PENNSYLVANIA FLEXIBLE METALLIC TUBING CO.

Established 1902

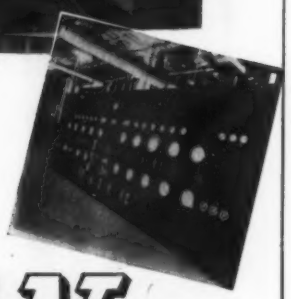
7211 POWERS LANE **PHILADELPHIA 42, PA.**



AUTOMATIC and CENTRALIZED CONTROL

Vulcan-designed distillation units and plants incorporate the latest developments in instrumentation. Through such automatic and centralized control, operating costs are kept at a minimum, uniformity of product quality is insured and overall high yields are guaranteed. Entire plant operations are controlled from a centralized control station, thereby eliminating costly variables which are bound to arise from obsolete manual operations.

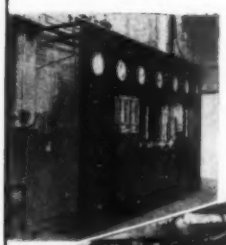
The Vulcan engineering staff, through long experience in the development and application of the best types of automatic control, is available to furnish this valuable experience to the chemical process industries for plant modernization and improved operational methods.

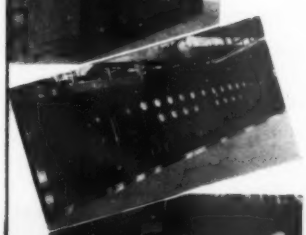


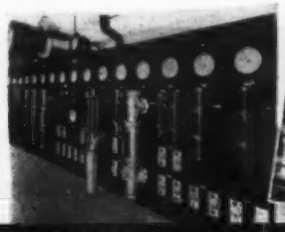
VULCAN

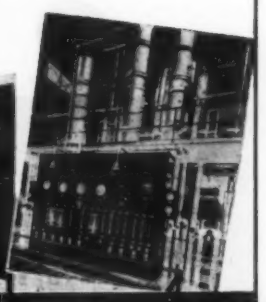
DISTILLATION
EVAPORATION
EXTRACTION

PROCESSES *and* EQUIPMENT





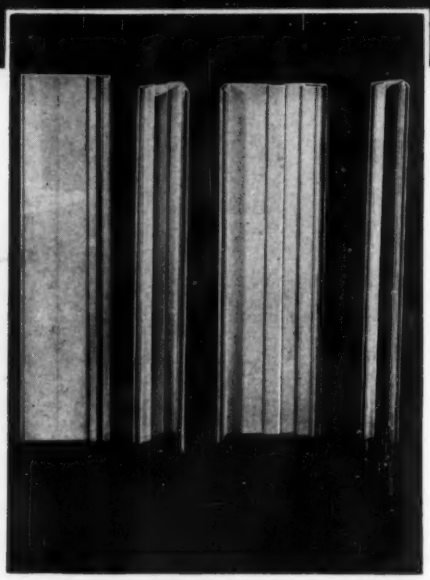




THE VULCAN COPPER & SUPPLY CO., CINCINNATI, OHIO

REFRIGERATOR BREAKER STRIP SECTIONS

EXTRUDED BY.. Sandee



THE ACCEPTED MATERIAL FOR BREAKER STRIPS

Plastics have long been **the accepted material** ***for breaker strips. Modern trends, however, demand better functioning and better looking sections.***

The refrigerator breaker strip sections shown above illustrate another milestone in Sandee's development of sound industrial applications for plastics.

Sandee, in close cooperation with several leading refrigerator manufacturers, has developed a number of *better* custom extruded snap-on breaker strips. Among other superior advantages they 1. greatly decrease assembly time, 2. eliminate unsightly screws, and 3. provide a pleasing contour to blend into general cabinet design. Available in white or appealing, contrasting, pastel tones.

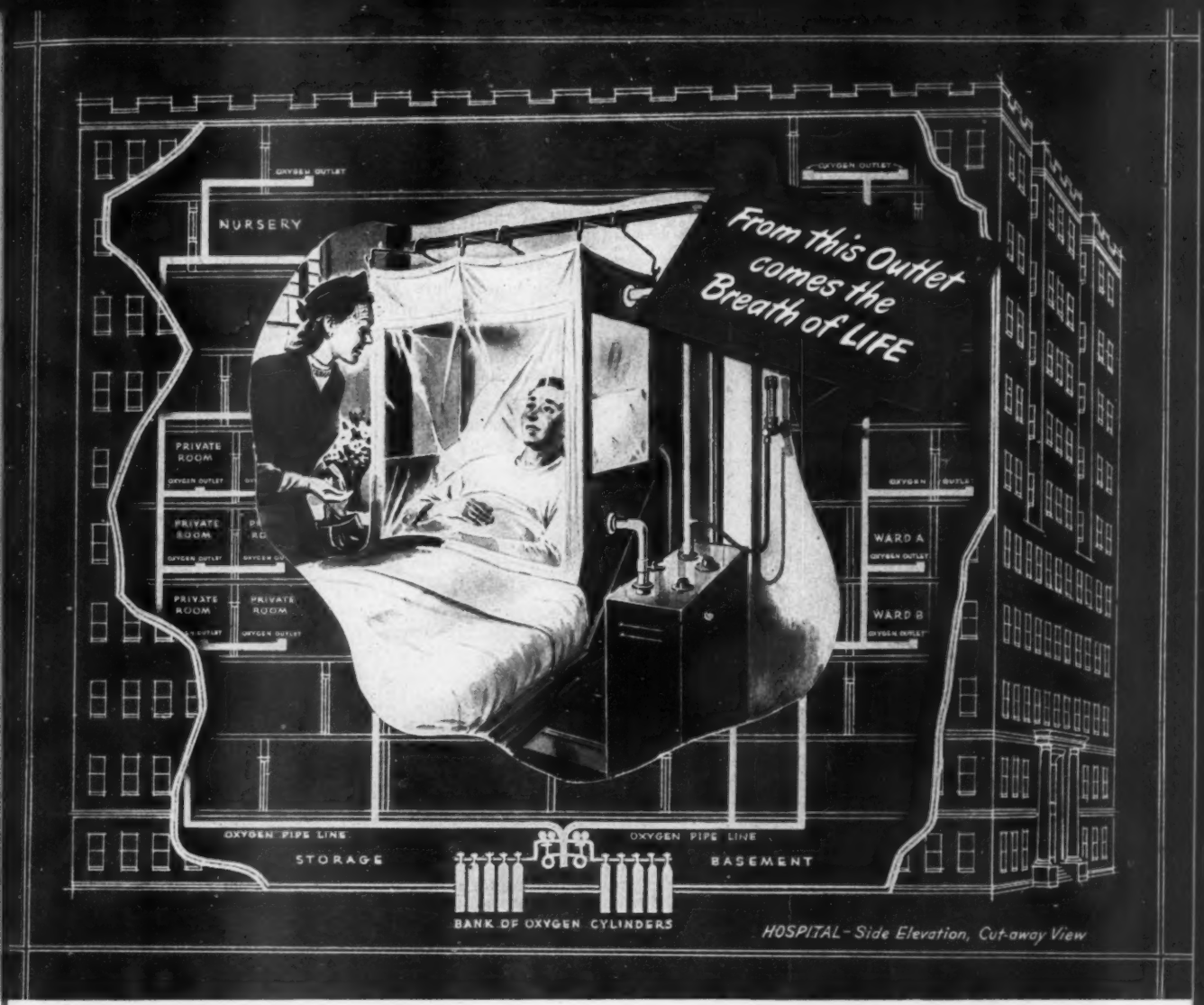
Again, our technical personnel can offer you the benefits of successful experience in the development of individual refrigerator parts as well as for other sound industrial applications.

SALES REPRESENTATIVES IN 19 PRINCIPAL CITIES

Sandee Manufacturing Company

3945 NORTH WESTERN AVENUE · CHICAGO 18, ILLINOIS

EXTRUDED PLASTICS AND SPECIAL TOOLS



HOSPITAL - Side Elevation, Cut-away View

OXYGEN TO BREATHE is the most important thing in the world to one who is ill and unable to get enough for life from the air alone.

The use of oxygen in medical practice has grown rapidly in recent years. Physicians have found it effective in the treatment of certain types of heart disease, shock due to wounds or injuries, following major operations, and for numerous other illnesses.

The need for extra oxygen is so frequent in hospitals that many of them, instead of depending on cylinders of oxygen brought to the bedside, now have convenient oxygen outlets in many rooms and wards. Oxygen is brought directly to the bedside through an unseen "pipeline" from a centrally located "bank" of oxygen cylinders.

Oxygen is a principal product of Units of UNION CARBIDE. It is supplied to hospitals—and in much greater amounts to industry for numerous mass-production operations—largely through The Linde Air Products Company.

Linde Oxygen is now so readily available that no one need ever be without oxygen for any purpose. Oxygen is but one of the many basic and essential products from UCC—materials which, all together, require continuing research and engineering work with over a third of the earth's known elements.

FREE: *Physicians, nurses, teachers, and others who would like more information on the availability of oxygen, and on the various types of oxygen therapy equipment, are invited to write for a copy of the* "OXYGEN THERAPY HANDBOOK." *Ask for Booklet P-11.*

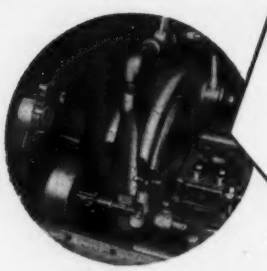
UNION CARBIDE
AND CARBON CORPORATION

UCC

30 East 42nd Street — New York 17, N. Y.

Products of Divisions and Units include—

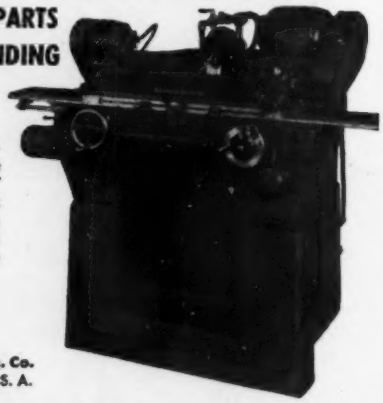
ALLOYS AND METALS • CHEMICALS • PLASTICS
ELECTRODES, CARBONS, AND BATTERIES
INDUSTRIAL GASES AND CARBIDE



.0002" TOLERANCE
PRACTICALLY
PERFECT ROUNDNESS
NO. 2 MICRO-FINISH

– this is No. 5's stated performance on grinding drum shafts – one of the most vital parts of a precision bombsight – produced in lots of 2000.

SUCH ACCURACY – CONSISTENTLY REPEATED –
SPEEDS SMALL PARTS
PRECISION GRINDING



No. 5 Plain Grinding Machine – made in two sizes – 3"x12" or 3"x18". Work speeds and table speeds are designed for diameters up to about 1".

Brown & Sharpe Mfg. Co.
Providence 1, R. I., U. S. A.

BROWN & SHARPE

Reg. U. S. Pat. Off.

Samson Cordage Works

Boston 10, Mass.

Manufacturers of braided cords of all kinds, including sash cord, clothes line, trolley cord, signal cord, shade cord, Venetian blind cord, awning line, etc., also polished cotton twines and specialties.

SPOT CORD

Reg. U. S. Pat. Off.

Our extra quality sash cord, distinguished at a glance by our trade-mark, the colored spots. Especially well known as the most durable material for hanging windows, for which use it has been specified by architects for more than half a century.

THE TABULAR VIEW

Philosophy of Librarianship is refreshingly discussed (page 25) by JOHN E. BURCHARD, '23, co-author of *The Evolving House: A History of the Home*, frequent writer on topics in science and architecture, stimulating contributor to The Review, and Director, Albert Farwell Bemis Foundation. It is in his capacity as Director of Libraries, however, that Professor Burchard deals with the scholarly utilization — rather than the mere storage — of the world's knowledge as a means to man's cultural advancement. The earnest gravity with which the Institute regards its library program is further indicated by the recent appointment of Dr. Vernon D. Tate (page 43) as librarian designee for the $2,500,000 Charles Hayden Memorial Library soon to arise on Cambridge's famed Memorial Drive.

Mechanistic Maneuvers forced upon man by the products of the technological age, provide the basis upon which the behavior of men and machines may be predicted. Drawing upon wartime experiences, PROFESSOR PHILIP M. MORSE stimulates thinking (page 29) in the application of operations analysis to peacetime problems. To an already brilliant career, well known to Review readers, Professor Morse has begun a new chapter in his acceptance of the directorship of the Brookhaven National Laboratory at Camp Upton, Long Island.

Minority Report (page 32) from TENNEY L. DAVIS, '13, reminds us — with ample historical documentation — that for all of the contributions of science, human nature is still human nature and not too well understood. After a lapse of several years, during which he has become director of research of the National Fireworks Company, Dr. Davis rejoins The Technology Review as one of its Editorial Associates and as one whose past writings have attracted wide comment.

Sun Gazing might well characterize the daily activities of DR. WALTER ORR ROBERTS who has been, for the past six years, superintendent of Fremont Pass Station, Harvard College Observatory, Climax, Colorado. His article (page 33) traces the development of the Lyot coronagraph whose use during the war was instrumental in predicting sunspot activity which interrupted transatlantic radio communication. A native of Massachusetts and graduate of Amherst and Harvard, Dr. Roberts completed one year of research at the Eastman Kodak Company in Rochester, but now prefers the sunny heights of Climax.

Inventive Productivity is not the exclusive sphere of youngsters, according to studies made by THOMAS SPOONER who followed his collegiate studies at Bates College with a four-year course at the Institute from which he was graduated in 1909. Indeed, Mr. Spooner points out (page 37) that training and maturity are as necessary for inventiveness as for any other activity. Since his graduation from the Institute, Mr. Spooner has been with the Westinghouse Electric Corporation in various responsible research and executive positions. He is currently manager of the Engineering Laboratories and Standards Department. (*Concluded on page 70*)

ONE MORE STRAW—ONE LESS CAMEL!

Many centuries ago the weight of one last straw broke a camel's back. Thus somebody's artless optimism about the strength of a vital part wrecked a perfectly good materials handling system.

Today it is plain, cold fact that ignoring the depressing effect of low temperatures on the impact strength of vital steel parts can be a short cut to a long line of avoidable, costly troubles.

The solution for the problem in the fable was less load or more camel. For the modern problem the answer is a molybdenum steel that combines the deep hardening and freedom from temper brittleness necessary to provide good low temperature impact strength.

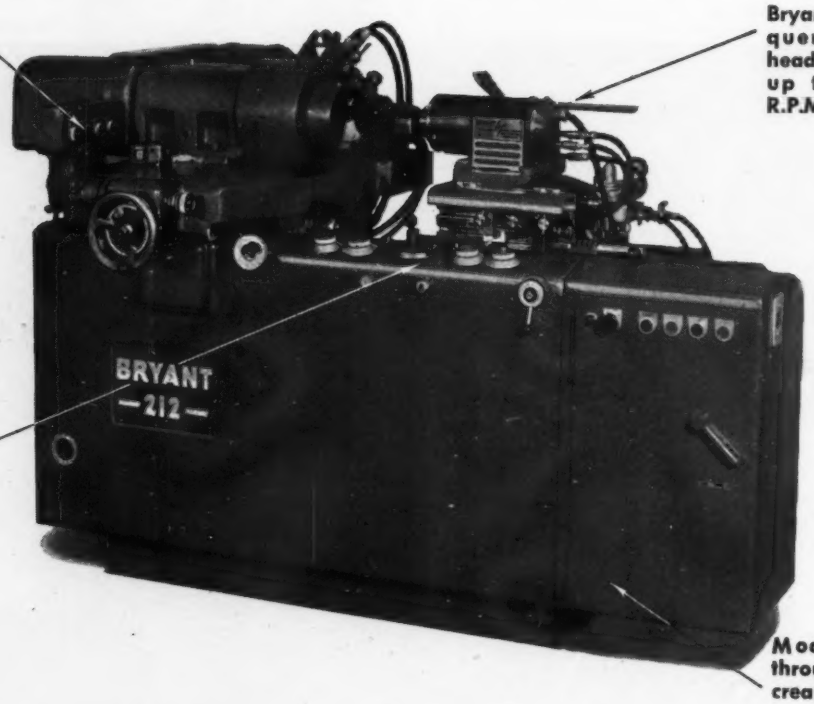
MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"
CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

Climax Molybdenum Company
500 Fifth Avenue • New York City

MOLY

Announcing a New Automatic High Production Internal Grinder

No. 212


Push button Cycle control
Bryant High Frequency Wheelhead for speeds up to 100,000 R.P.M.
Simplified, Centralized Operating Controls
BRYANT
—212—
Modern design throughout for increased efficiency

Another BRYANT Postwar Development

The new No. 212 Bryant Grinder is designed to fill the pressing need for greater production per man hour. It is a fully *automatic* internal grinder that requires a minimum of operator attention—in fact on many jobs one man can run two machines. Production is higher, more precise and more profitable with this new grinder.

The new No. 212 Bryant roughs and finishes bores from 1/16" to 6" (approx.) in diameter in lengths up to 3 inches. On the smaller bores, it is especially suited to the use of *Bryant High Frequency wheel spindles which operate at speeds up to 100,000 r.p.m.*

The No. 212 design incorporates the superiority of Bryant three point wheel slide suspension and insures maximum rigidity under all conditions. Movements of the machine are hydraulically operated, while the cycle is controlled electrically to facilitate change-over. Sizing is accomplished accurately and automatically by any one of three methods: a plug gage mounted in the work spindle, a diamond tipped bore contact, or controlled by the wheel truing diamond. It *roughs* and *trues* and *finishes* and stops *automatically*—producing parts with fine work finish to tolerances that insure bores that are straight and round, making the products which you manufacture more desirable because they run smoother and live longer.

If grinding figures in your production plan, your move for best results is to—

SEND For The Man From Bryant.

BRYANT

BRYANT CHUCKING GRINDER CO.

SPRINGFIELD, VERMONT, U. S. A.

more than 300...

100,000 barrels of ethylene per day is the capacity of this plant, designed and built by Lummus.

Lummus has designed and built over 300 plants for manufacturing ethylene, butadiene, phenol, alcohols, solvents, and other chemicals from petroleum and other source materials.

Petroleum is a low-cost source of these chemicals, and the market for them is expansive. It is estimated that chemical, pharmaceutical, and cosmetics manufacturers will invest a billion dollars in expanded facilities during the next five years.

With complete research and construction facilities and with broad experience in petroleum refining as well as in chemical production, Lummus is prepared to design and build for you a plant which will produce petroleum chemicals most economically.

Lummus engineers will gladly discuss with you the practical considerations of building or expanding your petroleum-chemical facilities.

THE LUMMUS COMPANY
420 Lexington Avenue, New York 17, N. Y.

LUMMUS

CHICAGO—600 South Michigan Avenue, Chicago 5, Ill.
HOUSTON—Mellie Esperson Bldg., Houston 2, Texas
LONDON—78 Mount Street, London, W. 1, England

Write for a cop[illegible] of the Postwar Petrol[illegible]

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for any application . . . in the type, size, range and style of graduation to suit your needs exactly . . . described completely and illustrated actual size . . . in the new edition of STARRETT DIAL INDICATOR CATALOG "L". Write for your copy.

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THE L. S. STARRETT CO.

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WORLD'S GREATEST TOOLMAKERS

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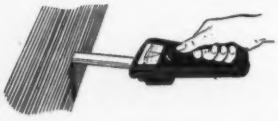
PRECISION TOOLS • DIAL INDICATORS • STEEL TAPES • HACKSAWS
METAL AND WOOD CUTTING BAND SAWS • GROUND FLAT STOCK

FOR CHECKING MOISTURE



HAND MODEL

Cambridge Moisture Indicators are convenient, quick-acting instruments used to indicate the moisture content of various hydroscopic materials. In the bayonet model the measuring element is enclosed in a blade for insertion into stacked and hung materials. In the hand model the instrument is placed directly on the surface of the material. Used chiefly in paper, processing, textile and allied industries. *Send for Bulletin.*

CAMBRIDGE
PRECISION INSTRUMENTS

CAMBRIDGE INSTRUMENT CO., Inc.

3707 GRAND CENTRAL TERMINAL, NEW YORK 17, N. Y.

MAIL RETURNS

Brooklyn's "High Road"

FROM BLAIR BIRDSALL:

The writer's attention has been called to the two articles entitled, "High Road to Brooklyn," by E. H. Cameron, which appeared in the May and June, 1946, issues of The Technology Review.

These articles are of such outstanding quality that I did not want to let them pass without comment. The author and the editorial staff of the publication are to be congratulated for a splendid piece of technical reporting which, unlike so much of this type of writing, must have a very strong appeal to the non-technical reader. Furthermore, to the best of my knowledge, the facts are all correct and in sufficient detail to give a clear and thorough bird's-eye view of the work, its background and its unique position in engineering history.

As a footnote to the articles, for those who are not aware of the incident, the following story may be of interest. The last War Loan Drive in December, 1945, coincided with the completion of the removal of the unsightly Brooklyn Bridge elevated station adjacent to City Hall Park in Manhattan. As a result of this work, it is now possible to see the Brooklyn Bridge from City Hall Park. These events were made the occasion for a little ceremony on the Bridge plaza entitled "The Re-Unveiling of the Brooklyn Bridge." Following speeches by several of the city officials, including the Borough Presidents of Brooklyn and Manhattan, Mayor LaGuardia arose to address the group. After a few introductory remarks, he announced that, although he realized he had had several notorious predecessors, he was sure that none of them had had the temerity to foist upon the public such a transaction as he now proposed to launch. This, he stated in effect, was nothing less than the sale of the Brooklyn Bridge to the highest bidder. With this he turned to an assistant, asking for the Brooklyn Bridge, and placed on the rostrum a three-foot scale model of the structure. The bids, of course, were to be in War Bonds. The first bid was in the neighborhood of $6,000,000. The second bid was for $17,500,000 — and the Mayor lost no time in knocking the bridge down for this figure. The successful bidder was a New York retail merchants' association.

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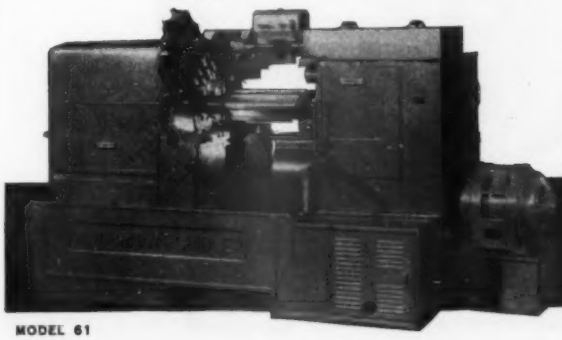

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This steel wire is made into tires

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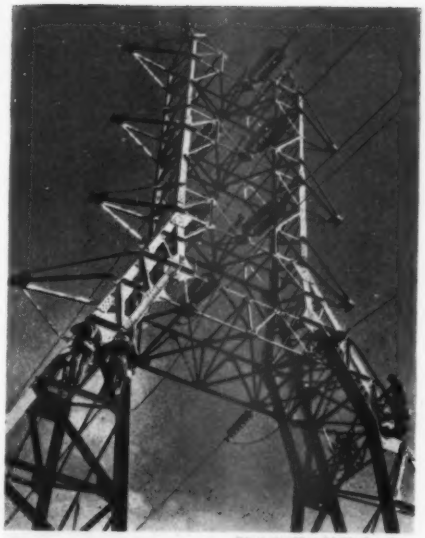

Photo by Harold M. Lambert
Transmission of Power

VOLUME 49 NUMBER 1

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Photo by S. M. Hall

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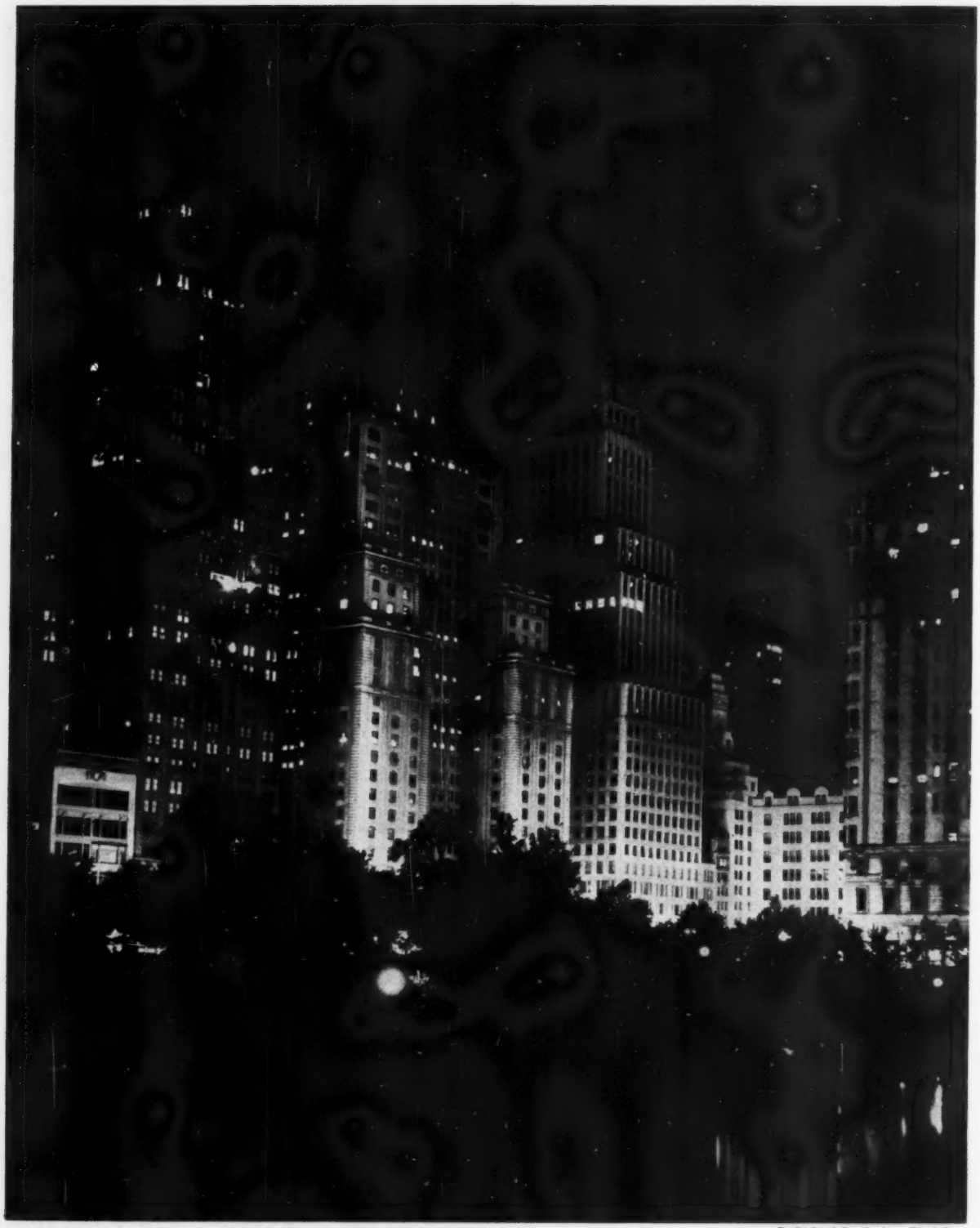


D. Richard Stutile, from Black Star

Turn the Nighttime into Daytime

The corner of Fifth Avenue and 59th Street, New York, offers an attractive view by day or by night

THE
TECHNOLOGY
REVIEW

Vol. 49, No. 1 November, 1946

The Trend of Affairs

Dollars from Guinea Pigs

A REMARKABLE feature of our current export trade is the expansion in the sale of penicillin, and — second only to the world-wide demand for that elixir of life — the growth and vigor of our overall export of drugs. Penicillin is one of the very few American products whose sales to foreign countries are exceeding by a considerable margin (about two to one in this case) the sales within the United States itself.

In 1938 this country exported about $17,000,000 worth of drugs and medicinals. In 1945 the sale to foreign markets of penicillin and sulfa derivatives, two drugs which did not even appear in the 1938 listings, exceeded $18,000,000. Even in regions where dollar exchange is scarce, demand for penicillin seems to be more intense than for any other item except food. The foreign demand for this comparatively new product has continued to grow so rapidly, however, that the last available export figures for 1946 show the monthly sales of penicillin to be about *ten* times the total monthly sales of all drugs in 1938. It will be remembered that the sale of penicillin for civilian use did not begin until May, 1944, and then it became available only on a limited scale, although penicillin was in fairly large-scale production in 1943 for military and research applications. By 1945 American production was more than 300 times the 1943 rate. While the United States remains by far the largest producer and exporter of this drug, Great Britain and Canada now have small surpluses for export and various other nations are producing part or all of their requirements.

That our drug exports in 1945 should be substantially larger than in 1938, the last peacetime year, is not altogether surprising. The war eliminated many competitors in this market, forced our drug industry to expand its capacity greatly and introduced American trade names and products into many new areas. More striking than the seven-fold increase in the value of these exports, however, has been the change in their character, which, in a sketchy way, may almost be regarded as a summary, or at least a reflection, of current progress in medicine. In most cases the items which now dominate our drug exports were not even mentioned in the 1938 list. Included among these new products in 1945 were $25,000,000 of vitamins and vitamin concentrates, $12,000,000 of penicillin, $7,800,000 of glandular products, $7,000,000 of sulfa drugs, and $5,000,000 of antimalarials, chiefly atabrine.

If these figures are impressive, it is not because of any direct effect on world trade statistics. In 1945 the United States spent $345,835,000 on one import item alone — coffee!

Sorghums—New Industrial Grain

ALTHOUGH known since the days of ancient Egypt and Assyria and mentioned in the Bible, grain sorghums have always remained minor members of the cereal family. Also called milo, kaffir, and durra, grain sorghums must be distinguished from common sorghum or sorgo, a plant raised for its sugary juice. Grain sorghums bear kernels composed mainly of carbohydrates and proteins, similar to the kernels of wheat, corn, and other common cereals.

But lately grain sorghums have developed important industrial utility. Previously, sorghums had not been used commercially because the more familiar grains long customarily used for industrial processes (corn for wet milling to make starch, barley for malt, rye for whisky, and so on) were usually plentiful. Furthermore, the original grain sorghums grew at such a height, and with such irregularity of stem and kernel, that they could be harvested only by hand — a crippling obstacle to large-scale growing. This latter shortcoming was eliminated, however, by development through genetics of a "combine type" of grain sorghum which may be mechanically harvested. Therefore, one man using agricultural machinery may now tend 160 acres of grain sorghums from plowing

time through harvest, an economy of man hours rare among agricultural crops.

Next, grain sorghums demonstrated striking ability to grow in semi-arid regions. Hence more than 70,000,000 dry acres of United States farmland, unable to grow corn or wheat profitably, can produce fine yields of grain sorghums. Recognition of this ability to thrive with little moisture led to trebling production of grain sorghums in this country during the decade beginning in 1934, with an annual total of 180,000,000 bushels reached by 1944. Such plentitude of grain sorghums proved to be most opportune during the war, because then production of the major grains flagged, food use demand for cereals increased, and in some instances, price structures made it more profitable for growers to feed grain to farm stock rather than to sell the grain off the farm.

During the resultant shortage industrial grain users, maltsters, brewers, distillers, syrup manufacturers, wet millers, and others used great quantities of sorghums to meet needs normally supplied by the conventional cereals. Furthermore, a waxy type of grain sorghum was perfected that supplied a replacement for tapioca, needed because imports of cassava root were stopped, the normal raw material for tapioca manufacture. Sorghums won favor in many of these emergency applications, and are still used.

Grain sorghums also have potential value as human food. They have, in fact, been consumed by African natives for centuries. But custom, rather than availability, and nutritive value determine what foods are eaten in any particular country, and grain sorghums are a bizarre food to the American consumer. Therefore, the future of grain sorghums lies not in food uses but rather in expanded industrial applications, where unfamiliarity never hampers adoption of a new raw material.

This pair of photographs, selected in part because of their almost mirror-image composition, are symptomatic of the Trend of Affairs in the Institute's current activities. Depicted are two of the chemistry laboratories which, after functioning in a program of research for the Chemical Warfare Service, have been renovated and are now in use in the greatly enlarged educational program at

Bataan and Its Aftermath

By Samuel A. Goldblith

TO the native and American defenders of the Philippines the events preceding and following the surrender of Bataan mark a tragic period of Twentieth-Century suffering. Certainly the inhumanities inflicted during the Death March must be thoroughly condemned. At the same time, some gratification, however slight, may be gained from the realization that a study of Bataan and its aftermath brings to light the need for a better understanding of food nutrition on the part of combat officers and men. Indeed, had such knowledge been more widely dispersed, it is probable that a considerable number of Bataan casualties might have been avoided.

The Japanese blockade of the Philippines in 1942 made it necessary for the defending Filipino-American forces to subsist entirely on what foodstuffs had been evacuated from Manila to Bataan Peninsula and — with the exception of a few submarine loads of food, ammunition, and medical supplies — what commissaries had been stored in Corregidor. As a result, the ration issued the troops was very small and, by January 6, 1942, all of the Army units were on quarter rations. But meals were served daily and usually these consisted of 10 ounces of rice per man, one can of milk per 10 men, one can of pink salmon per 10 men. Caribou or mule meat was issued in small quantities about once a week. Such was the dearth of foodstuffs that the 26th Cavalry, Philippine Scouts, were dismounted and their horses and mules slaughtered, and the meat issued to the troops. Another reason for killing the horses of the 26th Cavalry was the lack of horse feed. Other than small amounts for the hospital, no fresh or canned vegetables were available for issue at all.

By March, when rations were further reduced, malnutrition had affected everyone. In addition, actual starvation became serious in many cases. This was the condition of the Filipino-American troops just before the surrender of Bataan on April 9, 1942.

Technology. With a total enrollment in excess of 5,000 students (of which more than 3,000 are war veterans) such modernized and expanded facilities are by no means excessive — if indeed they are adequate — to cope with the Institute's share of a nation-wide problem. The unprecedented expansion in higher education has been particularly severe in the schools of engineering.

Having brought up fresh troops, many tanks, guns, and planes, the Japanese began a large-scale offensive on April 1, 1942. Because of starvation, coupled with three months of continuous fighting in the trenches and foxholes without relief, the Filipino-American troops began to retreat and were forced to surrender on April 9, 1942. At the onset of the last Japanese drive the defending troops were physically incapacitated to carry out the task they were forced to meet. Of the men in the 31st Infantry (United States) 80 per cent were on the sick list suffering from malnutrition, malaria, and dysentery. As a result of insufficient diet, their resistance was so weak that malarial attacks kept recurring and the men were getting weaker daily. At the onset of the last Japanese drive, this unit was in a rear area but was immediately ordered to the front. The only way in which the men could reach the combat zone was to march 10 minutes and rest 10 minutes, although normally, troops march 50 minutes and rest 10 minutes! Many of the artillery units which consisted of Filipino troops with American officers attached as instructors had hardly enough men available for one gun crew. These are but a few of many examples that could be cited to illustrate the complete exhaustion of our fighting forces on Bataan. It is the firm belief of many of the senior and medical officers that, had the troops of Bataan been on sufficient rations, the story of Bataan would have been much different.

The troops on Corregidor were on a diet somewhat better than those in Bataan; a little more beef and some vegetables were issued.

Immediately following the surrender of Bataan, the Filipino-American troops were ordered by the Japanese to march to San Fernando, Pampanga Province, a distance of 60 to 100 miles, depending in which part of Bataan they were captured. Even though in pitiful physical condition our men were forced to march 25 to 28 miles per day. This march, now known as the Death March, was conducted at the point of a bayonet; those who could not keep up were killed. Most of the troops were not fed at all for five to six days on this march. No distinction was made between officers and men. Finally when food was issued, each man received only a few spoonfuls of steamed rice. One American Army doctor who made the march, aptly remarked: "The men made the Bataan-San Fernando march on the marrow of their bones!"

As a direct result of the tremendous exertion of this forced march under a blistering tropical sun, the lack of food, and the completely inadequate supply of water (and that of very poor quality), many Americans and Filipinos soon died at the first Prisoner of War concentration camp at Capas, Tarlac Province, whence they were taken in closed box cars from San Fernando. Many more men were permanently disabled as a result of this march in which cardiac and gastro-intestinal ailments were the most prominent diseases. Many more were so weakened and debilitated that they easily succumbed to malaria, dengue fever, dysentery, and other tropical diseases. Deprivation of good drinking water on the march — one of the worst hazards of the tropics — necessitated the consumption of stagnant, impure river water along the march. This in itself brought about a great deal of dysentery and other enteric diseases. By October 4, 1942, more than 1,500 Americans and 27,000 Filipinos had died at Camp O'Donnel, Capas Tarlac, the first concentration camp. In July, 1942, most of the American prisoners at Camp O'Donnel were transferred to Cabanatuan, where the forces on Corregidor had previously been taken in June, and by October 4 in excess of 2,100 deaths had occurred there. Thus, out of a total of approximately 14,000 to 16,000 American prisoners of war more than 3,600 deaths occurred; whereas out of 60,000 to 70,000 Filipinos there were 27,000 mortalities, most of which can be traced almost directly to malnutrition. Early at Camp O'Donnel many cases of polyneuritis appeared.

What are the reasons for the higher Filipino death rate

in prison camp — 27,000 deaths out of 60,000 in a period of six months as compared to 3,600 deaths out of 14,000 American prisoners? One reason may be that the inherent stamina of the Filipino, a rice-eating people, was less than that of the American, a wheat-, meat-, and potato-eating nation. Another may be the superior education of the American people in personal and community hygiene and sanitation as compared to that of the average Filipino peon who made up the bulk of the recruits of the Filipino Army of 1941–1942.

The causes of deaths at O'Donnel and Cabanatuan are: (1) malnutrition, before and after the surrender; (2) malaria and dysentery, especially amoebic, coupled with the lack of drugs for proper treatment; (3) the march out of Bataan; (4) improper sanitary facilities.

Throughout Bataan and its horrible aftermath, the necessity of proper sanitary measures — especially such measures as might be practiced by the individual soldier — was never fully realized. For example, knowledge that three drops of tincture of iodine to a canteen of water would serve as an antiseptic water purifier when calcium hypochlorite tablets were not available, saved the lives of many men on the Death March. Many more men would not have contracted amoebiasis had they been trained in such simple facts of protective sanitation as this.

An elementary knowledge of nutrition helped save the lives of quite a few men. In Cabanatuan, many officers and men did not contract scurvy simply because they permitted the mungo bean which they were issued to sprout and then ate both the beans and the sprouts. It is a common nutritional fact that whereas fresh mungo beans are practically devoid of vitamin C, they are relatively high in this anti-scorbutic vitamin when allowed to sprout.

Knowledge of how best to spend their money for foods so as to obtain the dietary factors they needed most was of great advantage to some of our soldiers. Peanuts, a very cheap foodstuff in the Philippines, are very high in protein and fat. Many of the men spent 80 centavos for a can of corned beef obtaining thereby about 80 grams of protein, whereas for this amount of money they could have obtained about 400 grams of protein from peanuts. These are but a few examples of how many men benefited in those times of stress from an elementary knowledge of the simple facts of sanitation and nutrition. We may, regrettably, record that many more died because they were ignorant of facts such as those given above.

Had all officers commissioned in our armed forces received training in nutrition and personal and community hygiene and sanitation, they undoubtedly would have been better able to take care of the health and welfare of the men under them and to purchase food and equipment more wisely. Bataan served as an excellent example whereby such knowledge meant the difference between survival or death through judicious use of what few materials there were at hand.

The White Sands Proving Ground

WHILE the United States did not establish the first proving ground for heavy liquid fuel rockets, it now has the largest field which, in time, may also be the best equipped. The Secretary of War approved the establishment of this proving ground for long-distance rockets and guided missiles on February 20, 1945. The site had been previously selected by a representative of the Office of the Chief of Ordnance and representatives of the Engineer Corps. It is an area of desert land extending for 125 miles due north into the state of New Mexico from the New Mexico-Texas state line north of El Paso, Texas.

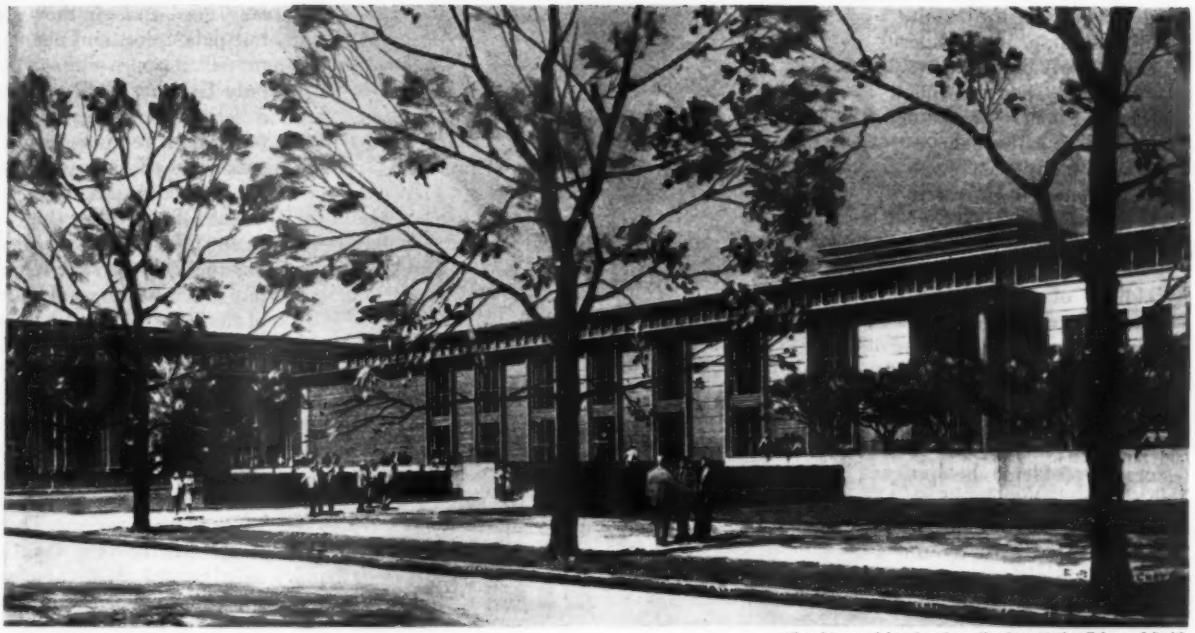
The area is a typical southwestern desert with a sparse vegetation of sagebrush and tumbleweed but with a few special features. In the northern section there are some beds of black lava produced by a long-extinct volcano, while the east-central section shows immense shifting dunes of blinding white gypsum sands. In 1933 this area of the white gypsum sands had been made into the White Sands National Monument. Since the rocket testing area embodies the site of the (former) National Monument the whole proving ground has been officially named the White Sands Proving Ground.

The proving ground is of a generally rectangular shape, narrowing toward the southern base line. In the north it is 41 miles wide, in the south, 25 to 30 miles. The launching area and the permanent facilities, such as the control blockhouse with its 10-foot concrete walls and its pyramidal roof with a maximum thickness of 27 feet of reenforced concrete, the launching towers and launching platforms, the test stands for rocket motor tests, and the facilities for the personnel are located in the southern section of the proving ground, within sight of the Organ Mountains. A specially built highway connects the launching area with United States Route 70 which crosses the southern part of the proving ground diagonally. In the West, Route 70 leads to Las Cruces, New Mexico (a distance of about 30 miles). In the East, Route 70 leads to the Alamagordo Air Base, just outside the borderline of the proving ground. Connection to El Paso, Texas, is via Las Cruces. United States Route 80 leads from Las Cruces to El Paso, a distance of slightly more than 60 miles.

The proving ground itself is actually a valley — 4,000 feet above sea level. It lies between two mountain ranges, the San Andres Mountains in the West, and the Sacramento Mountains in the East. Both of these ranges ascend to 6,000 feet measured from the valley floor, or 10,000 feet above sea level.

The first work done on the proving ground was in connection with the testing of captured German V-2 rockets. At the end of July, 1945, transportation of about 300 carloads of V-2 parts to White Sands got underway. A total of 25 rockets were assembled from these parts. The first rocket actually to rise from the proving ground was not a captured V-2 but an American high-altitude rocket built by the Douglas Aircraft Company. It had an overall length of 16 feet and a diameter of one foot and was fired with the aid of a booster unit. It reached an altitude of 230,000 feet.

After the firing of this missile the first ground tests of captured V-2 motors was begun in March, 1946. The first ascent of a V-2 took place in April, 1946, followed by the ascent of May 10, 1946, to which the press had been invited. Since then there have been other launchings. One of the V-2's exploded at take-off near the ground; another one at an altitude of about 5,000 feet. Most rockets reached an altitude of about 80 miles. One record shot took place on July 30, 1946, when an altitude of 104 miles was reached; another occurred on October 10, when a rocket stayed aloft 11 minutes, attained a speed of 3,600 miles an hour, and reached an altitude of 102 miles.



All architectural drawings from Voorhees Walker Foley and Smith

Architect's drawing of the front of the Charles Hayden Memorial Library on Memorial Drive, and connecting Building 2 of the main group of Institute Buildings (left) with Walker Memorial

The Wreck of Matter and the Crush of Worlds

Cultural Scholarship, through More Effective Ways of Utilizing the World's Knowledge, Is the Philosophic Basis for the Charles Hayden Memorial Library

By John E. Burchard

> *". . . scarcely had I opened the fatal box than some blue cards escaped from it, and, slipping through my fingers, began to rain down. Almost immediately, acting in sympathy, the neighboring boxes opened, and there flowed streams of pink, green, and white cards, and by degrees, from all the boxes, differently colored cards were poured out, murmuring like a water-fall on a mountain-side in April. . . . Issuing from their inexhaustible reservoirs with a roar that continually grew in force, each second increased the vehemence of their torrential fall. . . . Overwhelmed, desperate, pitiable, his velvet smoking-cap and his gold-mounted spectacles having fallen from him, he vainly opposed his short arms to the flood which had now mounted to his arm-pits. Suddenly a terrible spurt of cards arose and enveloped him in a gigantic whirlpool. During the space of a second I could see in the gulf the shining skull and little fat hands of the scholar; then it closed up and the deluge kept pouring over what was silence and immobility."*
>
> *Preface to* Penguin Island
> Anatole France (Evans tr.)

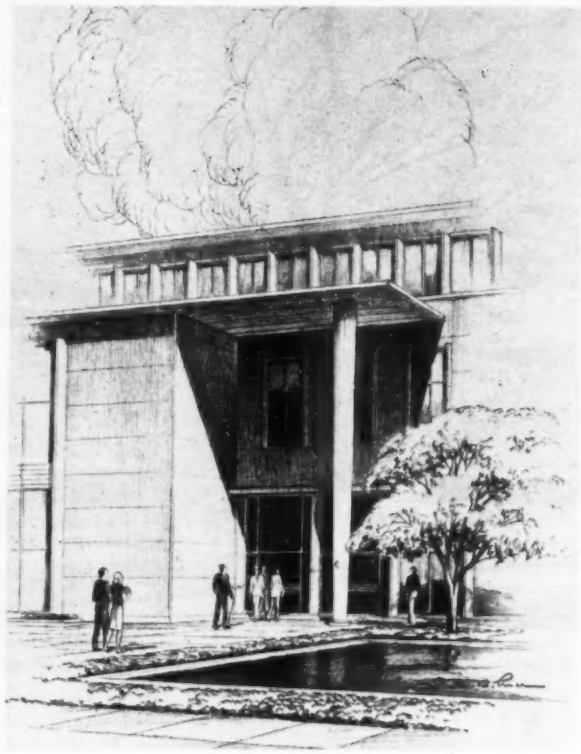
POOR Fulgence Tapir, the penguin scholar, drowned in his own cards, may have been, and most likely was, the victim not of volume but of sloppy mechanical arrangements. He had stored his cards too high and too precariously. He had a great many cards for his day, enough to drown him, in sooth. But now there are enough references to drown everyone. Indeed a change of our title from "worlds" to "words" will provide appropriate expression of the fear, enunciated with increasing frequency, that the human race may "suffocate from its own intellectual excreta."

At least three theses have been advanced as solutions to this dilemma. One comes from an experienced librarian, one has recently been restated by a young biologist, the third is the proposal of a nationally famous scientist, administrator, and engineer.

Dr. Fremont Rider, Librarian of Wesleyan University, has been a serious student of bibliothecal matters for years. He has collected statistics on the growth of university libraries. When he boldly extrapolates these data

into the future the results are frightening. If, as Rider says, scholarly libraries have, on the whole, doubled their holdings each 16 years of late, and if, as he believes, this rate will persist indefinitely, Harvard University will have 8,000,000 volumes in 1962; 16,000,000 in 1978; 32,000,000 in 1994. Holdings of other institutions will grow proportionately, some perhaps even faster. "Where are all these books to be put?" asks Rider.

Looking merely at the storage problem, he proposes the reduction of the contents of a volume to a single printed card by microphotographic processes which are currently possible (or almost so and which are certainly conceivable) coupled with appropriate magnifying equipment for the reader. By such a process a book of 250 pages might be stored on a three by five inch library card and filed, if you will, in the card catalogue itself. Evidently some 250 books could be kept where one now rests. With such a system in operation Harvard University, which now can store 4,000,000 volumes with not too much difficulty, could take care of 1,000,000,000; even if the geometric accretion were to persist at the present rate, Harvard would have her library hatches battened down until the year 2074. After that, of course, she would be back where she is now and would have to double her warehouses every 16 years. But that is not important. The year 2074 is quite as far ahead as anyone now living need worry about.



Detail of entrance to the proposed Charles Hayden Memorial Library

The Librarian's Real Problem

The fault with Rider's proposal is not that the inexorable laws of the geometric progression will finally catch up with it. The real difficulty is that it takes no account of the basic problem of librarianship which is never storage but always use. The problem of library institutions is not to see to it that between them they have in store every piece of recorded information. By the way, we miss this objective by a large margin, even in the opulent United States. The real problem is to make what is in these records quickly available to the scholar, and certainly in his lifetime. Information which never gets out of the printed document and into the mind of a man is useless.

Rider might reply fairly that even the present halting and possibly archaic methods of classifying library contents are hardly understood or utilized at all, even by trained scholars. It is regularly a source of consternation, to those who know what tools are available for reference, to observe that able persons are unaware that the tools exist. These tools can provide veritable palanquins for the lazy even though they are but palanquins and not jet-propelled space ships. Yet only Goucher College gives a serious course in library tools and requires all its graduates to have passed a rigorous examination in their use. At Technology there is little difficulty in persuading the student that it will pay him to make a full study of the slide rule. But what a trivial instrument the slide rule is compared with knowing the combination to the vaults which contain the treasure of man's past thought!

But this essay is not an apology for librarians. There is no justification for the silly canard that they are only happy when they have procured all the books they can get — and have them all safely locked up in the library. They worry about the real problem much harder than their colleagues on university faculties. They worry hard enough; whether imaginatively enough is another matter. One can contest Rider's extrapolation. But even if it be accepted, it is as plain as a pikestaff that a solution of the mere storage problem will do almost no good; that the present library reference methods will be inadequate for such a mass of material as is sure to be produced even if they are better than most people appreciate. The trouble with the Rider proposal, then, is that it faces only part of the difficulty — and the lesser part at that.

Disposal of the Unfit

If Rider's is only a partial solution, one occasionally proposed by natural scientists is no solution at all. The most recent statement of this position is that by Dr. Garrett Hardin in the September, 1946, issue of *The Scientific Monthly*. In a satire, which makes it a little difficult to tell where the author is kidding and where he isn't and approaching the problem from the unilateral position of the natural scientists, Hardin offers a solution which is simplicity itself. The librarian has simply to be ruthless. He must throw away library material and do this much more rapidly than he accumulates it.

It is possibly true that scientific literature has a way of purging itself. A Mendel may come along and his little paper may make obsolete and useless to the scientist the thousands of pages published by the precedent Slawkenbergiuses. From the point of view of a practicing scientist perhaps all this antecedent material could then be burned. Since science has, from time to time, changed its mind about some important matter and backtracked to the concepts of some earlier and possibly "obsolete" individual, the practice of this theory might entail some risk even for science. There is question whether the scientific

thinker would be quite so enthusiastic about such a program as the scientific tradesman might be.

But it is none the less true that a very large percentage of the material which the scientist wants in his daily life will be contained in such summary landmarks, especially when combined with a periodical literature (usually of the last decade) which advances from such a milestone. From time to time the current literature can be totted up again and a new milestone placed. Thus, for science alone, there may be some merit in such a proposal and Hardin may not have been fooling when he made it.

The weakness of such a proposal, of course, lies in the fact that scientific literature is a very small part of all literature. In spite of the present awesome position of science, its writings are by no means the most important of recorded thought. The really frightening thing about the atomic bomb is not that scientific literature has helped us to know too much about nuclear fission, but that other literature has helped us too little to know human relations. Parenthetically, it is discouraging to note that though scientific education was capable of producing the genie of the atomic bomb, it failed to provide a background which would have warned that the world would be too small for evil purposes even if the whole atomic bomb complex were nothing but a bad dream.

No, for all literature the task is clearly not one of throwing away. No one is wise enough or fair enough to undertake such a clean-up task. One can let the case rest on human mental limitations and not adduce the catastrophe which would occur if the task were undertaken by men of prejudice (as are all men) or men of ill-will (as are many men). Hitler, for example, simplified the problem of librarianship for Germany but did not add either to the intellectual stature of his country or to its contributions to human progress and welfare.

If the Western world comes to debacle it will not be because we know too much about atomic bombs but because we do not know enough about the human animal. On this greater problem man's mind has been working since the beginning of time and has been rather fully recording its work since the zenith of Greece. The minds which have worked on it have been no less profound than those which spawned the atomic bomb. They have had to wrestle — and still have to wrestle — with imponderables; imponderables, at least, in any existing scales, and possibly forever imponderables. They have contradicted each other completely and no one has arisen, and perhaps no one will ever arise, to be their Mendel. Not alone the scholar but also the simple thoughtful common man has to work through a great deal of material in such a field to arrive at conclusions which finally are somewhat personal. He cannot arrive at them by contemplation of the periodical literature of the past decade or the past century.

Indeed, if he relies on Lippmann, Pearson, and Pegler, rather than on the literature which has stood the test, he will almost certainly come out with a magnificent lack of proportion; on the other hand, for everything Pegler suggests he can find a more thoughtful and rational exposition in some literature of the past.

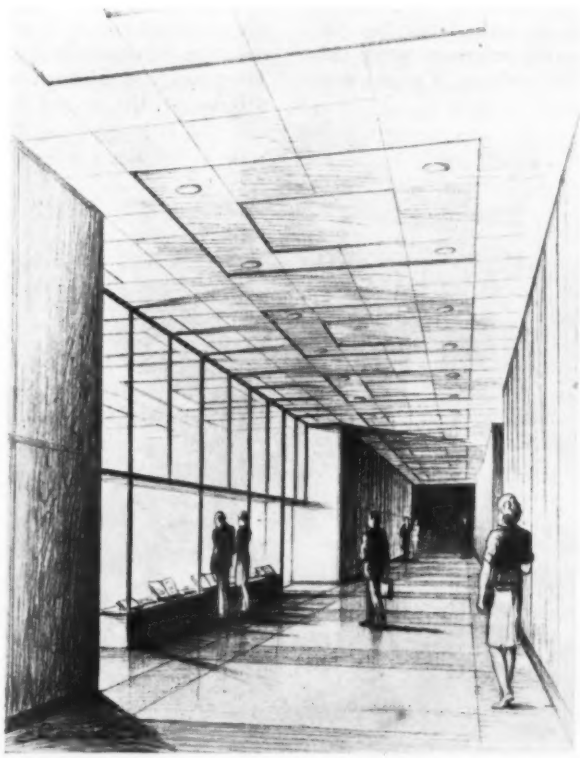
It is, of course, true that it does not require 4,000,000 volumes to yield this sense of proportion. The serried pedestrian rows of the history and record of Clavering St. Mary will not in themselves throw any light; indeed they may obscure it. It is also true that there is more food for thought in the hundred volumes of Dr. Stringfellow Barr than any one mind can digest; it is certain that a list of 5,000 titles could be compiled which would embrace all important thought. It is mathematically demonstrable that, given nothing else to do, no one man could peruse and digest even this fragment of human literary endeavor — this eighth of one per cent of the holdings of Harvard University — in fifty years of steady reading.

Reserved for the Scholar

The rationalization by which universities continue to accession these gigantic collections is that they serve the scholar. On that rationale it is possible to defend the volume which lies on the shelves in the dust for fifty years, if on the fifty-first someone finds it, dusts it off, digs into it, and draws some conclusion from its contents — useful or not. This fifty-year fate is, of course, not unusual in the large library. At the University of Chicago 95 per cent of the books account for but five per cent of the circulation.

One has to look at the word "scholarship" pretty hard. Most of the time it seems to be represented by the trivial production by the candidate for a degree of D.Litt. or Ph.D. Forced to be original, whether he is or not, and in a world where a lot of scholarship has preceded him, he rummages in the dust of the library, digs up some little-used material, and produces an essay of incredibly small import. This type of scholarship is out of date and will, it is to be hoped, ultimately disappear from the university.

When it does, it will have to be admitted that there are not enough true scholars on any one campus to justify



The Avenue of Culture which will join the Charles Hayden Memorial Library with Institute buildings

the maintenance of these Gargantuan holdings, and that there is no particular reason, save that of pride, why a university should force an extramural scholar to come to its particular campus to carry on his work. It will then be possible to think about the sort of university library, coupled with some further extra-university system, that would best serve the undergraduate, the graduate student, then the faculty, and finally the outside scholar wherever he may be.

Something New Must Be Added

None of these, it may be clear, will be well served by an application of Rider's proposal without something more; and all of them will be hurt by an application of Hardin's. For something which will yield more promise we have to turn to the third thinker, Dr. Vannevar Bush,'16, and his article on the Memex in *The Atlantic Monthly* for July, 1945.

Dr. Bush is a thoughtful man and he knows at first hand the possibilities implicit in present-day machinery and especially in rapid selectors and calculators. Leaving out the part which deals with providing a private desk drawer of information for the individual scholar, the Bush proposal amounts to supplying a proper diagram of all knowledge, so coded, that by application of any one of a number of existent, or easily conjectured rapid-scanning devices, the references which the scholar seeks can be picked out from multitudinous references in a very short space of time. On the mechanistic side this is entirely feasible almost at once.

Even on the intellectual side, it is immediately applicable to matters where only factual data is sought. The weight of an isotope, the height of a tower, the alkyl compounds with specific common properties, all sorts of readily classifiable things could, by some labor, be suitably coded. For much of scientific reference work this simple scheme might be useful; in addition, it might even be sufficient.

When one passes beyond fact to the area of conjecture or discussion the problem becomes less simple. None the less, Dr. Bush has provided a stimulus which could lead to a grandeur of library service never before seen. To bring it about will require a concatenation of several forces, some very difficult to stimulate, human nature being what it is. Of these factors the mechanical ones are the nearest to being ready for application. As in so many other fields the potentials of apparatus have far outstripped the capacity of human co-operation.

Still, it is not entirely out of the question that these forces might be brought into action; it is, in any event, not idle to hypothesize about them and from the hypothesis to construct the picture of a Wellsian library system, even if with less imagination than Wells would have brought to the conjecture.

Philosophy of New Approach

Let us imagine, then, that all the Brobdingnagian collections have been transferred to two repositories: one, primary and active; the other, duplicate and inert and existing as insurance. On a national basis these can be as large as they need to be and micro-cards for compactness can be adopted or not, as is desirable. After these two major collections have been established perhaps a good deal of the residue throughout the country may be destroyed, although dead storage might be better since disasters have occurred to book accumulations.

The central depository cannot, of course, be anything like a warehouse. It may have to be supplied with a new form of cataloguing having nothing to do with present subject methods ut used solely to make it possible for page boy or machine to find a specific volume unerringly and at once. When found the work may be set before a televisor and viewed by a distant scholar over wire or by radio, in the institution from whence the request came. The process of intercommunication by which the scholar will be at the screen at the *(Continued on page 64)*

The general reading rooms, one of which is shown here, are aimed to provide commodious seclusion for study and relaxation

Of Men and Machines

Airplane Attacks on Submarines Have Little in Common with Better Automobile Traffic Systems. Yet, Their Common Element Promises Clearer Insight into Man's Behavior

By Philip M. Morse

IN the last few years the scientists of this country — customarily thought of as residing in ivory towers to contemplate the wonders of nature — were introduced to many new problems and tasks requiring immediate solution. In addition to their normal activities, they were called upon, by the exigency of a national emergency, to assume the responsibilities of research engineer, production superintendent, and administrator. Yet the multiple personalities which many of them bore will be of benefit to them, for our scientists go back to their laboratories with increased administrative experience and a broader understanding of technological-social problems which are bound to be useful in their future work. They have had wholesale opportunity to witness the benefits to be derived when all branches of science are directed toward the solution of a common problem. In the process they have demonstrated that biological techniques and points of view are sometimes helpful in solving problems in physics; that mathematics can be a powerful aid in furthering psychology; that a silver lining in the study of nuclear physics has given medical men new ways to save countless lives; that the method of science is applicable to social as well as to technological problems. More important, their firsthand experience with administrative problems will make them better organizers and managers of their laboratories; it should also make them better citizens.

Perhaps the most useful result which may be expected to come from this large-scale eviction from ivory towers is an increased application of scientific methods to the broader problems now facing the world. Scientists contributed their own points of view and techniques in solving organizational and operational problems of the war; they developed promising methods of analyzing these problems, which, if properly utilized, are bound to have permanent value in peacetime. The application of scientific method to the study and improvement of the operations of men plus machines has come to be called operational analysis or operations research. As the names imply, it is a study of the operations themselves, not of the component equipment or men separately. Its results were of great practical value in the improvement of operations of war; we may expect the same techniques to show equal usefulness in fields of industrial and governmental operations.

In his final report, Admiral E. J. King comments on the usefulness of operations research to the United States Navy. He says, in part: "The late war, more than any other, involved the interplay of new technical measures and opposing countermeasures. In this see-saw of techniques the side which countered quickly, before the opponent had time to perfect the new tactics and weapons, had a decided advantage. Operations research, bringing scientists in to analyze the technical import of the fluctuations between measure and countermeasure, made it possible to speed up our reaction rate in several critical cases. The knowledge resulting from continued cross-check of theory with practice made it possible to work out improvements in tactics which sometimes increased the effectiveness of weapons by factors of three or five, to detect changes in the enemy's tactics in time to counter them before they became dangerous, and to calculate force requirements for future operations."

The procedure which was developed for studying an operation is an obvious one to the technical man: The operation is analyzed to find out what does happen rather than what should happen; the combined knowledge of physics, chemistry, psychology, and other sciences is utilized to find out why a particular operation occurs the way it does; this deeper understanding suggests possible causal relationships which might be tested by operational experiments, and the finally tested understanding can then be used to modify the operation to give best results under various conditions.

To be of greatest use, operations research must be an experimental, not a historical, science. For this reason the most effective operations research groups during wartime were attached to high command levels, where the broader operational problems arose and where the action necessary to implement an operational experiment could be ordered. In peacetime, also, operations analysts must have direct access to the industrial or governmental official in charge of the operation to be studied, or their work will have little practical value.

Very few persons would quarrel with the program outlined above. In fact, in its general aspects, it has been applied many times in economics, business management, and politics. But a new and significant extension of this general plan, put into effect during the war, brought about highly beneficial results in a critical period when the saving of time was all important. Something new had been added; something new was discovered. The new ingredient was the co-operative effort of teams of specialists, drawn from any and all branches of science. In the solution of important problems, these teams were free to carry on a program of operations in which considerable emphasis was placed on the experimental method, and they combined their knowledge and techniques to achieve the maximum of the desired goal in the shortest period. In short, the new ingredient was merely the effective use of the integrated knowledge of highly trained specialists.

The new discovery was that such a program, simple though it appears, involved procedural and organizational problems of considerable difficulty which had to be overcome if the plan were to be at all effective. Once these purely human problems were overcome so that the activities of administrators and operations analysts were harmoni-

ously supplemented, astonishing improvements were achieved.

The procedural problems arise in part because administrative officials, military and nonmilitary, seldom realize that many of their problems are amenable to scientific study; they arise also because the scientist, who is to study the operations, must often take a point of view diametrically opposite from that of the administrator who is running the operation. The administrator must often make arbitrary decisions and is usually impatient of skepticism, whereas the scientist must always be skeptical and is often irritated by arbitrary decisions. Yet for operations research to achieve its full usefulness the administrator and his operations research staff must work in the closest partnership. The administrator makes the final decisions but depends on the scientist to give him a deeper insight into the situation before his decision is reached; the operations analyst is free to investigate all aspects of the operation but reports his findings to the administrator for his final action. Such close partnership was eventually achieved in some military staffs here and in England during the war, and it paid large dividends. Similar partnership should be possible in other fields with equally gratifying results.

Measurement, the Basis of Knowledge

One of the important things the analyst brings to the administrator is a quantitative picture of the problem, for one of his first tasks is to measure the operation. At first sight, the obtaining of meaningful numbers with which to measure the success of an aircraft attack on a submarine or of an automobile traffic regulation, for instance, would seem to be a contradiction of terms. We might expect each pilot to have his own method of attack and each driver to exhibit his own reaction to the regulation. It turns out, however, that operations can be measured, for nearly all operations today are those involving men *and machines*, and the machines force regularity on operations involving them.

The uniformity of behavior of equipment and men is not usually apparent until a number of similar operations have been compared, for this uniformity is usually of a statistical nature. For instance, of the U-boats sighted in daylight by British aircraft during the summer of 1941, about 40 per cent could be attacked before they managed to submerge. Fluctuating only between 35 and 50 per cent, this fraction remained essentially constant for nearly two years. When the United States entered the war, sighting reports on this side of the Atlantic showed that for all of 1942 this fraction was between 40 and 45 per cent, even though our type of plane and training methods differed from those of the British. Once it was discovered that the attack-sight ratio held constant for reasonably long periods of time, the optimum ordnance for submarine attacks could be predicted with considerable accuracy. Furthermore, it became possible to determine the value and relative advantage of plane attacks on surfaced submarines, compared to other kinds of military operations, the probability of success for which could likewise be ascertained.

Other operational quantities which remained remarkably constant were the ratio of fighter planes lost to enemy fighters shot down, and the number of ships in a convoy sunk by a single attacking submarine. Similar constants must be inherent in traffic operations, in rail transportation, and in public housing, to name a few peacetime examples.

The constancy (and therefore predictability) of operations involving men and equipment is at least partly the result of the machinelike manner in which men are forced to act in dealing with mechanized equipment. Such behavior may be deplored by poets but it should be the basis of hope for social scientists, economists, and systems engineers. It is important in that, within certain limitations, the behavior of men and machines can be experimented with, measured, computed, and predicted. Viewed from this more general point of view, the technique of operations research can certainly be applied to the study of peacetime operations.

Such studies should draw upon both the physical and biological sciences as well as on the physical sciences and mathematics, particularly the calculus of probabilities. The laws governing the sighting of a submarine by an aircraft observer depend upon the contrast between the normal ocean surface and the wake of the submarine, the optical transmission properties of the atmosphere, the methods by which a person's eye scans a large area, the sensitivity of the eye retina to contrast, and the altitude and speed of the plane, Some of these quantities are physical, some physiological; they all are measurable. The sighting of the oncoming aircraft from the submarine depends on a similar set of physical and physiological quantities. The relationship between these two sets of quantities determines the fraction of U-boats which have insufficient time to submerge before the aircraft attacks them.

Photo by Harold M. Lambert

Nearly all operations today are those involving men and machines — and machines force regularity on operations involving them

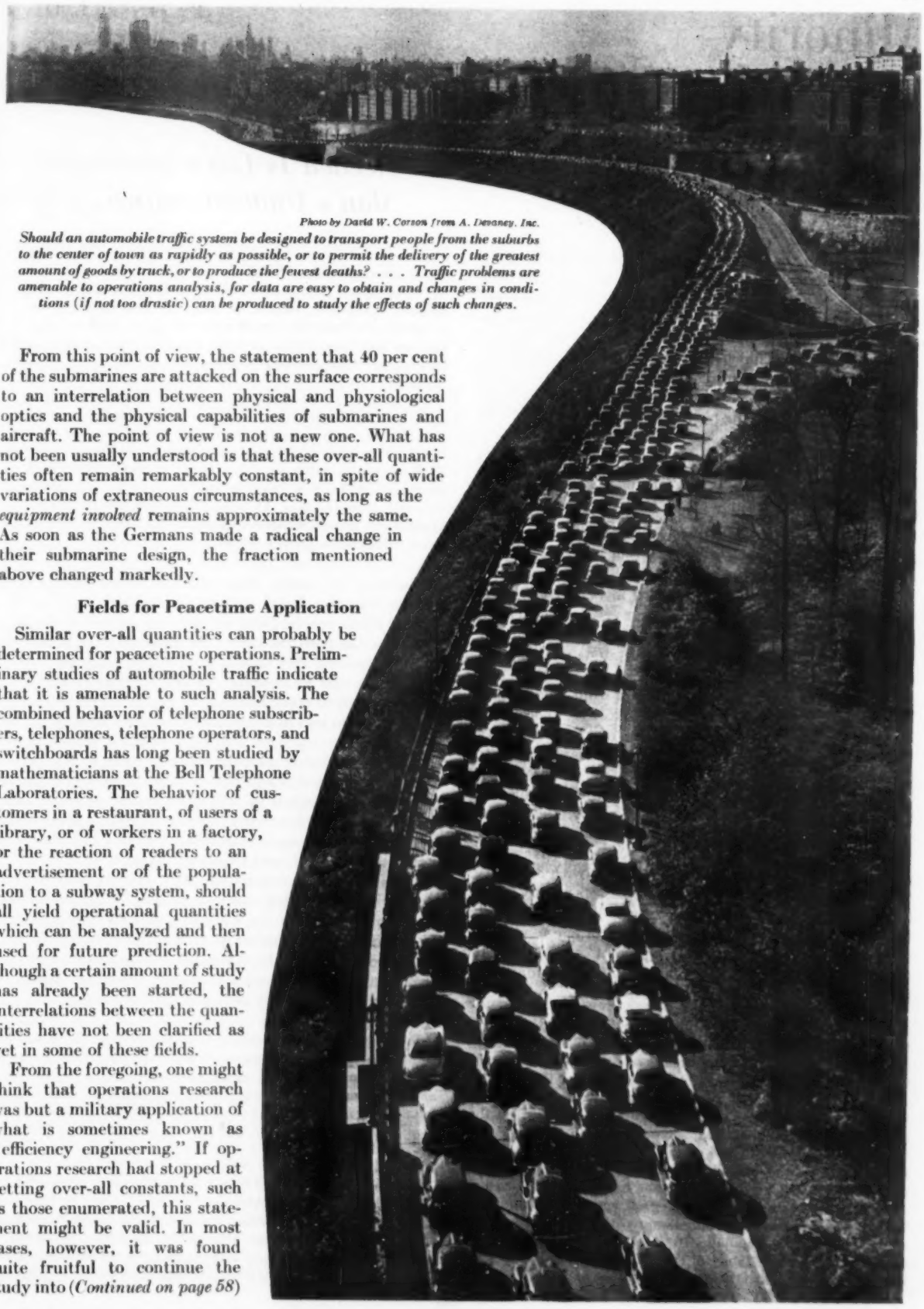


Photo by David W. Corson from A. Devaney, Inc.

Should an automobile traffic system be designed to transport people from the suburbs to the center of town as rapidly as possible, or to permit the delivery of the greatest amount of goods by truck, or to produce the fewest deaths? . . . Traffic problems are amenable to operations analysis, for data are easy to obtain and changes in conditions (if not too drastic) can be produced to study the effects of such changes.

From this point of view, the statement that 40 per cent of the submarines are attacked on the surface corresponds to an interrelation between physical and physiological optics and the physical capabilities of submarines and aircraft. The point of view is not a new one. What has not been usually understood is that these over-all quantities often remain remarkably constant, in spite of wide variations of extraneous circumstances, as long as the *equipment involved* remains approximately the same. As soon as the Germans made a radical change in their submarine design, the fraction mentioned above changed markedly.

Fields for Peacetime Application

Similar over-all quantities can probably be determined for peacetime operations. Preliminary studies of automobile traffic indicate that it is amenable to such analysis. The combined behavior of telephone subscribers, telephones, telephone operators, and switchboards has long been studied by mathematicians at the Bell Telephone Laboratories. The behavior of customers in a restaurant, of users of a library, or of workers in a factory, or the reaction of readers to an advertisement or of the population to a subway system, should all yield operational quantities which can be analyzed and then used for future prediction. Although a certain amount of study has already been started, the interrelations between the quantities have not been clarified as yet in some of these fields.

From the foregoing, one might think that operations research was but a military application of what is sometimes known as "efficiency engineering." If operations research had stopped at getting over-all constants, such as those enumerated, this statement might be valid. In most cases, however, it was found quite fruitful to continue the study into (*Continued on page 58*)

Minority Report

By Tenney L. Davis

Of All Knowledge, That Most Needed Is Least Developed—Man's Understanding of Man

MAN is a being who admires the products of his own ingenuity. Moreover, he admires his own ingenuity as well. He pauses in his occupations from time to time to look upon his works and finds them good. Then, like little Jack Horner, in the nursery rhyme, he perceives and acknowledges what a really smart fellow he is. Here, if he were simple he would stop. But man is complex, and commences to wonder whether he may not perhaps be too smart for his own good. Thus far he has gone with the atomic bomb. He was smart to discover a means of access to the energy of atomic fission. He was smart, so he thinks, to invent the atomic bomb; but he begins to think that he might have been smarter not to have made use of it, and to wonder whether he hasn't invented a monster which will swallow him up. He has become fearful of his own ingenuity, afraid of his cleverness, apprehensive lest his ingenuity fail to provide him with defenses against the weapon which it has contrived.

The Syracusan scholar, who discovered the so-called Pythagorean theorem, relative to the squares on the hypotenuse and on the sides of a right-angle triangle, felt that he had pried too far into the secrets of the gods, and committed suicide by throwing himself from a high place into the sea. Had he allowed himself to live, there is no telling what blasphemies he might have attempted.

Greek fire which the engineer, Kallinikos, brought to Constantinople about 672 A.D., gave its possessors an immediate and decisive advantage over their enemies. It became the top secret of the ancient world, and was so effectively guarded that it was never revealed. Greek fire secured victories for the Byzantines during seven centuries or longer, and we do not now know with certainty what it was or how it was used. Good secrets are, by tradition, divine secrets, and divine secrets have special advantages for safety and security. Some of these are evident in the advice which the Emperor Constantine VII (Porphyrogennatos, 905–959) gave to his son Romanos in the treatise "De Administrando Imperio":

> Thou ought above all other things to give care and attention to the liquid fire which is thrown by means of tubes; and if anyone dares ask it of thee, as has often been done of us, thou ought to repel and reject the request by responding that this fire was shown and revealed by an angel to the great and holy first Christian emperor, Constantine. By this message and by the angel himself he was enjoined, according to the authentic testimony of our fathers and of our ancestors, not to prepare this fire except for Christians only, and only in the imperial city, and never otherwise, not to transmit it and never to teach it to any other nation whatsoever. Then the great emperor, as a precaution against his successors, caused imprecations against the man who should dare to communicate it to a foreign people to be engraved on the holy tablet of the church of God. He ordered that the traitor should be held unworthy of the name of Christian, of all responsibility and of all honor; that if he had any office, he should be deprived of it. He declared him anathema through the cycle of the centuries; he declared him infamous, whether emperor, patriarch, prince, or subject, who should have attempted to violate this law. Further, he ordered all men having the fear and love of God to treat the prevaricator as a public enemy, to condemn and deliver him to the most frightful tortures.
>
> For all this, it once happened, since wickedness always pursues those in high positions, that one of the empire's great, won over by immense gifts, communicated this fire to a foreigner; but God could not see such an atrocity unpunished, and one day, when the guilty one was about to enter into the holy church of the Lord, a flame descending from heaven enveloped him and devoured him. All minds were seized with terror, and thenceforth no one, whatever his rank, has dared to plan, much less to execute, so great a crime.

The real or pseudo Roger Bacon (about 1250), who, first among the Latin writers of northern Europe described black powder, was not yet acquainted with guns, and knew the performance of his material only in rockets and firecrackers. But he was profoundly impressed by it; so much so that he hesitated to set down its composition plainly for all to read. Instead, he described it cryptically in an anagram and in a problem of algebra, and appended to the obscure piece of writing a remark which shows that he appreciated the possibilities of the stuff: "Whoever will rewrite this will have a key which opens and no man shuts, and when he will shut, no man opens." The things which black powder does are done for keeps. And this is as much as an atomic bomb can do. The effects of explosives are final, and therefore tragic.

Guns came into use about 1350. During several centuries black powder seemed wholly marvelous and scarcely suitable for the use of chivalrous fighters. Herman Boerhaave, lecturing in 1732 to his students in Leiden, discussed it in about the same tone as news writers of 25 years ago discussed poison gas or as congressmen in 1946 have been talking about the atomic bomb:

> It were indeed to be wish'd that our art had been less ingenious in contriving means destructive to mankind; we mean those instruments of war, which were unknown to the ancients, and have made such havoc among the moderns. But as men have always been bent on seeking each other's destruction by continual wars; and as force, when brought against us, can only be repelled by force; the chief support of war, must, after money, be now sought in chemistry.
>
> Roger Bacon . . . had found out gunpowder, wherewith he imitated thunder and lightning; but that age was so happy as not to apply so extraordinary a discovery to the destruction of mankind. But two ages afterwards, Barthol. Schwartz, a German monk and chemist, happening by some accident to discover a prodigious power of expanding (*Concluded on page 62*)

By Walter O. Roberts

Sun and Earth

Artificial Eclipses of the Sun and Their Importance to Radio Communication

ECLIPSES of the sun are rare astronomical events of great scientific value. Only when the sun, the moon, and the earth are very nearly in a straight line can eclipses of the sun or moon occur. For study of the atmosphere of the sun, an even rarer circumstance than a simple eclipse is necessary. That eclipse must be a total eclipse of the sun by the moon. The entire obscuration of the sun's bright face by the moon occurs, on the average, less than once per year anywhere on the entire surface of the earth, and then at best for less than eight minutes in a narrow band of totality which stretches across the earth, usually from end to end of the sunlight zone. At a given point of earth an eclipse occurs, on the average, only once in each 360 years.

For more than 100 years astronomers have sought to devise specialized instruments for the production of artificially eclipsed images of the sun. To be sure, it is a simple thing to occult the sun's image in a telescope with a small disk of steel of appropriate size. But unfortunately all attempts prior to 1930 to produce artificial eclipses failed to reveal any trace of the sun's tenuous corona, so spectacular at eclipses. The difficulty lies in the tremendous brightness ratio between the sun's luminous surface, and the faintly incandescent atmosphere of the sun. That difficulty has been circumvented in the modern coronagraph in a fascinating way.

To today's astrophysicist an eclipse of the sun is not simply a natural phenomenon of great beauty. It is also an event of immense scientific importance, for then the sun's atmospheric features — the chromosphere, the prominences, and the corona — become spectacularly visible. These features are of vast significance to our understanding of the physical processes within the sun and the effects of solar variations upon the earth.

A glimpse of the prominences and corona during total eclipse is a thrilling sight. The brilliant, sharply defined, irregularly shaped prominences glow with a purplish hue owing to the presence of strong spectral lines, the intense pair of lines of ionized calcium in the violet, and the similarly intense line of hydrogen (hydrogen-alpha) in the red. These gases are the primary constituents of prominences, and of the chromosphere, which appears to be a brilliant low-lying layer of prominence gases just above the luminous surface of the sun.

The pale greenish-white, more nearly symmetrical, and diffuse light of the corona, on the other hand, completely surrounds the eclipsed face of the sun as a more or less uniform halo upon which are superimposed long faint streamers of light. The coronal gases consist in part, as the recent identifications by Edlén[1] indicate, of very highly ionized iron, calcium, and nickel. But the coronal light, upon spectral analysis, shows not only the lines of the highly ionized gases, but also a continuous spectrum of very low intensity, the origin of which is uncertain.

The physical conditions evidenced by the prominences and corona differ enormously. A detailed unraveling of the causes and effects of these differences is one of the aims of the establishment of artificial eclipse-producing instruments. By further study we hope to improve our understanding of the association between complex events in the sun and their subsequent influences upon earthly life and activity.

The prominences and corona in the sun's atmosphere are highly tenuous clouds of gas in a condition of physical equilibrium that is very hard to explain. The boundary of the sun's surface is sharply defined. The narrow layer of the chromosphere, directly above this sharp surface, is irregular at its upper edge, and emanates a bright-line spectrum in contrast with the continuum of the sun's body. The thousands of absorption lines in the sun's spectrum undoubtedly arise below the chromosphere in the boundary between the sun's surface and the lighter gases of the atmosphere. Above the chromosphere, multitudes of tiny short-lived spike-like prominences may be seen, as well as an occasional larger, more brilliant prominence. The prominences, strangely enough, are not at all diffuse, but possess the most extraordinary wealth of sharp detail. In addition, all prominences are in motion (sometimes with velocities of several hundred miles per second) under the action of unknown forces.

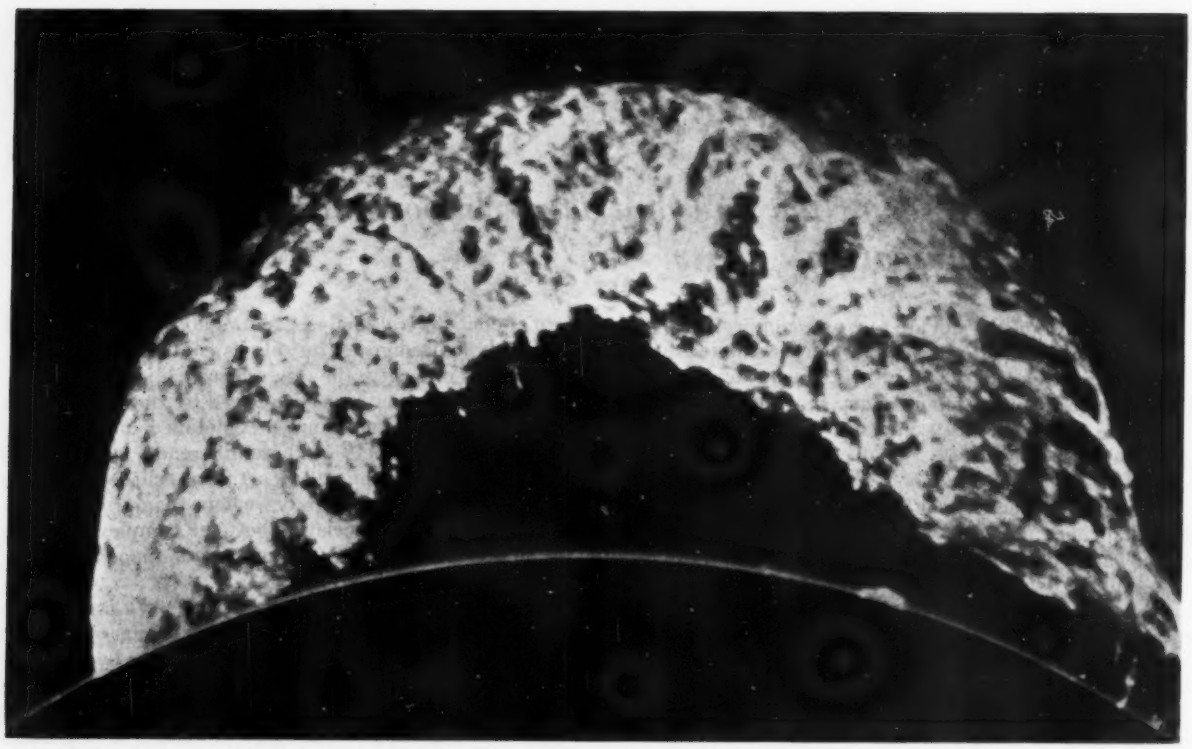
The corona, likewise, possesses a wealth of detail, although its general shape is more nearly uniform than the prominence configurations. It resembles a vast halo of light. The excitation temperatures required to produce the highly ionized coronal spectrum lines are measured in millions of degrees — much higher than the surface temperatures of the sun itself, and much higher than the prominence excitation. The reason for this high temperature of the corona is one of the great mysteries of the sun which we are striving to solve, and with the solution will come many interesting corollary facts about the sun.

Producing "Artificial Eclipse"

The first successful observations of prominences without a solar eclipse were made independently by Jannsen and Lockyer[2] in the year 1868. They were able to view the prominence spectrum and to get some idea of the prominence shape and size by widening the opening of an ordinary spectroscope slit placed just at the edge of the image of the sun in a small telescope. The reason for success was that the prominence lines were sufficiently intense to register when the spectral zone admitted to the

[1] Edlén, Bengt, *Arkiv för Matematik, Astronomi och Fysik*, April, 1941. (Stockholm, Sweden: Almqvist and Wiksells Boktrycheri A-B.)

[2] *Eclipses of the Sun* by Samuel A. Mitchell. (New York City: Columbia University Press.) See page 137.



Prominence of June 4, 1946. This is the largest prominence ever photographed with the coronagraph at Climax. The prominence was eruptive, and disappeared out of the camera picture very shortly after this photograph was made.

image was restricted, and the diffused background light from the sun's continuous spectrum was thus eliminated by the dispersing prism of the instrument. Within about 20 years it became possible to obtain photographs of prominences of very good quality.

The modern form of the apparatus, called a spectroheliograph, is now used at a number of observatories throughout the world. One of the most highly developed of these is located at the McMath-Hulbert Observatory at Lake Angelus, Michigan, where the apparatus has been perfected to permit rapid-sequence photographs of the prominences which can be viewed in motion with a motion picture projector. Spectroheliographic studies at the McMath-Hulbert Observatory have also been extended to the remarkable features of the sun's surface, the "plages" and "filaments" which can be viewed in monochromatic light.

The corona, however, has not yielded to simple spectroheliographic investigation. Seventy years passed between Jannsen's first prominence observation without eclipse and Lyot's first detection of the corona without eclipse. The story of the repeated attempts of many of the greatest astronomers of all times to photograph the corona without an eclipse is a fascinating one. Indeed, so discouraging was the repeated failure of astronomers to photograph either the corona or its spectrum that in 1929 the following statement appeared in the technical literature: "It is completely hopeless to try to photograph the corona, except during eclipse, even in the farthest red, or from high mountains."[3]

One year later, in 1930, Dr. Bernard Lyot, of Meudon Observatory in France, succeeded where all others had failed. At the suggestion of Professor Henry O. Barnard, Lyot had investigated all sources of unwanted sunlight scattered into the image of the artificial eclipse produced when an occulting disk is placed at the focus of a telescope lens. Lyot then devised ways to eliminate or vastly reduce all of these sources of unwanted glare. The result was a successful coronagraph. A diagram of the Lyot-type coronagraph [4] is given on page 35.

Lyot had found that ordinary astronomical instruments diffused many hundreds of times the amount of light that the corona radiated into them. He then set about to design a telescope, now known as the Lyot-type coronagraph, which circumvented the objectionable diffusion present in all preceding types of telescopes. Lyot's work in developing this instrument is one of the outstanding accomplishments in experimental astronomy.

Importance of Coronagraph

The advantage of a coronagraph over observations at total eclipse is obvious. With a coronagraph we may observe the corona and prominences at any time when the sky is clear, and by using networks of coronagraphs it should be possible for us to keep continuous records of the activity of the sun's atmosphere.

Features of motion which could never be detected during the brief moments of a solar eclipse are strikingly evident in rapid-sequence motion pictures covering several hours. A coronagraph allows observation of the very faintest prominences and of the brighter portions of the

[3] H. Kienle and H. Siedentopf, *Astronomische Nachrichten*, Volume 235, p. 10, 1929. (Kiel, Germany: Georgoheim.)

[4] Lyot, Bernard, *Monthly Notices of the Royal Astronomical Society*, Volume 99, p. 580, 1939. (London, England: Royal Astronomical Society.)

corona, but as yet no instrumental means can show us the fainter extensions of the corona that may be seen so readily during eclipses.

Still further, a coronagraph is an instrument of very critical sensitivity to dust, atmospheric haze, and lens imperfections of certain types. Its successful operation demands skies which are of utmost purity — and this usually requires remote, high altitude locations. But in spite of its temperamental qualities, the coronagraph, when equipped with the new birefringent crystal filters (which isolate narrow spectral bands of light) becomes one of the most powerful astronomical tools ever devised.

Several coronagraphs now operate in various parts of the world. In addition to Dr. Lyot's powerful instrument on the Pic du Midi in southern France, there are two other European coronagraphs. One is located in Switzerland, and the other, in Germany, was established during the war by the German Luftwaffe.

In the United States Dr. Donald H. Menzel, a native of Colorado, was largely responsible for establishing the coronagraph of the Harvard College Observatory at Climax, Colorado, in 1940. At an elevation of 11,500 feet the Harvard coronagraph is the highest permanent astronomical station.

For photographing in the light of narrow spectrum lines a spectroheliograph could be used. With the Harvard coronagraph, however, a newly developed astronomical tool known as the birefringent filter[5] is used. This remarkable instrument acts as a filter which is practically monochromatic. The one now in use at Climax transmits a band of color only about four angstrom units wide, as compared with several hundred angstroms for the best colored-glass filters. The filter was made by Dr. John W. Evans, who has developed the theory of such instruments to a considerable degree, and has designed some still sharper and more versatile filters which we hope soon to be able to build. Briefly, the filter consists of a multiple-layer sandwich of polaroid and quartz. Each quartz unit is cut so that it produces constructive light interference for some given set of wavelengths which pass through the filter freely, and destructive interference which stops the transmission of light of intermediate wavelengths. A number of such units are made so that their constructive interference wavelengths occur for only one or a few wavelengths; for all other wavelengths destructive interference stops the light in one or another layer of the filter sandwich.

The remarkable features of such a unit are that it can be built into a small container only six inches long, and that when it is placed in front of the film in a coronagraph it will act in much the same fashion as a spectroheliograph. Its advantage over a spectroheliograph is the absence of moving parts and adjustable narrow slits. The units so far completed do not possess quite the versatility of a spectroheliograph, but for application in a coronagraph their simplicity and compactness are great advantages. Moreover, the image quality which can be transmitted through birefringent filters certainly equals or exceeds that of most spectroheliograph apparatus.

The prominence photograph accompanying this article has been taken with the coronagraph with the birefringent filter. Lyot has also designed and used such filters, and much credit for their development must be given to him. With his apparatus he has taken some remarkable sequence photographs of the corona. Dr. Edison Pettit at Mount Wilson Observatory likewise uses equipment similar to the unit which we employ.[6] Dr. Pettit's apparatus has been used exclusively for prominences.

Results of Research with the Coronagraph

The applications of the results of a coronagraphic study of the sun's atmosphere are many, ranging from results of immediate practical importance to results of long-range fundamental scientific significance.

The sun is the source, directly or indirectly, of almost all of the energy utilized by man on earth. As a consequence, the variability of the sun is a vital concern to man in his adjustment to life on this wandering planet.

The fundamental position of solar energy in regulation

[5] Evans, John W., *Publications of the Astronomical Society of the Pacific*, Volume 52, p. 305, 1940. (Stanford University, California; Stanford University Press.)

[6] Pettit, Edison, *Publications of the Astronomical Society of the Pacific*. Volume 53, p. 171, 1941. (Stanford University, California: Stanford University Press.)

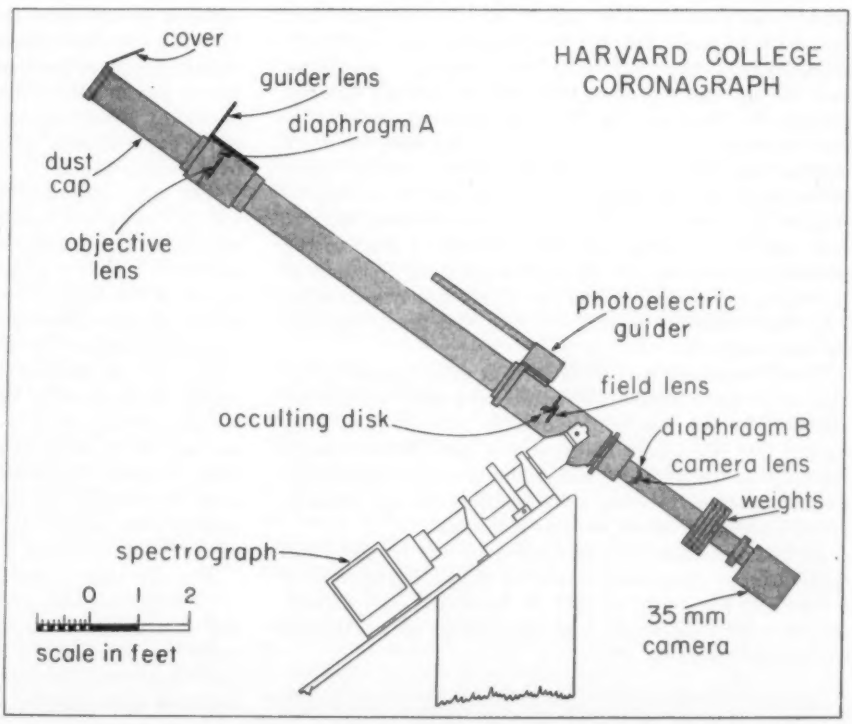
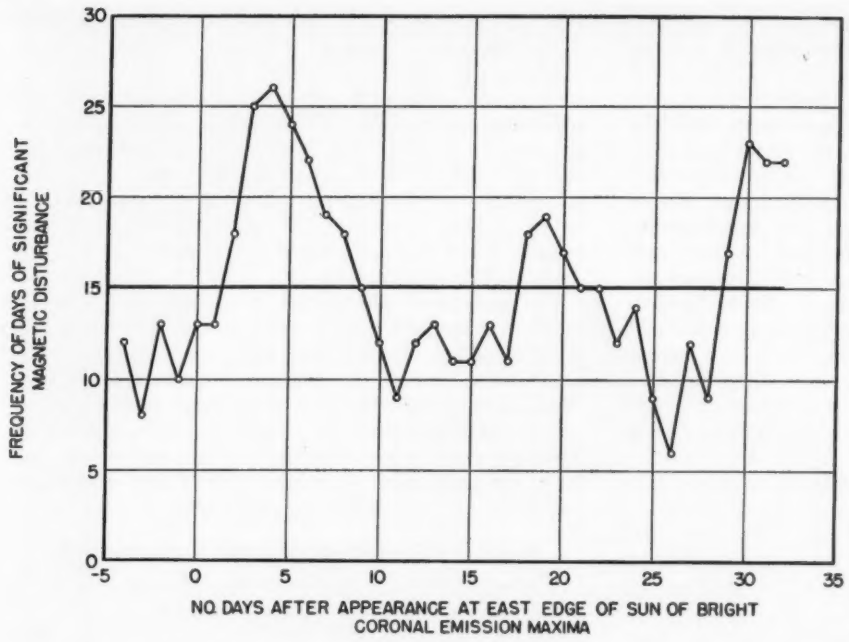


Diagram of the essential elements and general construction of the coronagraph devised by Lyot



Correlation of geomagnetic disturbances with areas of bright coronal emission on the sun

of human activity renders important all knowledge concerning the sun. The prominences and corona, being accessible to observational study (unlike the interior of the sun) and being closely associated with basic physical conditions, form two major objects of solar investigations.

As an example of the unexpected results of coronagraphic studies of the prominences, it is possible to point out the discovery in 1943 of an entirely new type of prominence activity of very short duration. Many prominence films showed, on some frames, tiny spikes of prominence gases which are now called "spicules." A film made especially to show the spicules reveals their uniformly short lifetime, averaging only four minutes, and shows that the spicules represent tiny jets of material expelled through the sun's surface. They are so frequent that it is believed they may form a possible link between the sun's interior and the sun's corona. If further studies verify this supposition, the spicules may go a part of the way to explain the corona's fantastically high temperatures.

In addition to being suspected of holding clues to the fundamental stability of the heat-generating processes of the sun, the prominences and corona are closely associated with the important cyclical and irregular fluctuations of the sun's activity.

These fluctuations have important effects upon earth, and thus upon man's activities on earth. Terrestrial weather, for example, is undoubtedly controlled by solar energy. Dr. Bernhard Haurwitz, of the Massachusetts Institute of Technology, has outlined a new hypothesis that solar flares produce substantial upper air motions which have subsequent weather influences.

As yet, the study is complicated by the irregularities introduced by the configurations of complex geographical features of the earth, so that we have had only enough success with long-range solar forecasting of weather to encourage us to keep it up.

But there is clear evidence that solar changes affect weather, or, at least, growing conditions. The pioneering work of Dr. Andrew E. Douglass,[7] for example, shows that the rate of growth of trees, as evidenced by the patterns of annual growth rings, is directly associated with the well-known 11-year solar activity cycle, which has been popularized as the "sunspot cycle."

The field of solar-terrestrial correlation is an important one and a dangerous one. The establishment of causal relationships among imperfectly associated physical phenomena is difficult. The interpretation of apparent associations of various effects on earth of the sunspot cycle must be approached with greatest caution.

Another highly important relationship between the changes in the sun and influences on earth has been established beyond doubt, however. This is the relationship of solar activity to the electrical and magnetic conditions of the earth and its atmosphere. The needle of a highly sensitive magnetic compass, for example, varies in strange harmony with fluctuation of the radiation from the sun.

The occurrence of brilliant northern lights, an electrical phenomenon of the earth's atmosphere, is stimulated by unusual disturbances in the sun's equilibrium. In some cases, violent disruptions of telegraph and electric power circuits follow solar upsets. In most cases any abnormalities in the magnetic fields of the earth are also accompanied by abnormalities in the behavior of the ionosphere of the earth upon which depends all radio communication over long distance.

The most spectacular result of our coronagraphic research during the war years has been the discovery of a new relationship between the sun's corona and the geomagnetic behavior of the earth. The nature of this result is shown in the graph, above, in which the frequency of days of abnormally distributed magnetic conditions is plotted vertically against the number of days which elapsed between the appearance at the east edge of the sun of a region of abnormally bright coronal emission. The spectacular maximum at +4 days indicates that, in the test period for which the graph was constructed (August, 1942, through December, 1943), the probability of magnetic disturbance on the fourth day was about 2.5 times greater than on the third day before, or the eleventh day after, the appearance of the maximum.

For the trial period, the second maximum shown at +19 days indicates an increased probability of magnetic disturbance about 15 days after the main maximum. The third maximum at the right results from the fact that the sun rotates once in approximately 27 days for the coronal features under study, and from the fact that the probability of magnetic disturbance (*Concluded on page 56*)

[7] *Climatic Cycles and Tree-Growth* by Andrew E. Douglass. (Washington, D. C.: Carnegie Institution of Washington. Volume 1, 1919; Volume 2, 1928; Volume 3, 1936.)

Age of Invention

Training and Maturity Yield Dividends at the Patent Office with Peak of Inventive Productivity Occurring for Men in Their Forties

By Thomas Spooner

INVENTIONS are usually made by men under 40, often without scientific training." This remark is reported to have been made by Sir James Swinburne, formerly President of the British Institute of Plastics Industry. It intrigued me. Is this true, and if so, what of the implication that men lose their mental creative powers before they are 40 years old? Does Sir James refer only to those inventions which have been of great commercial or social importance, or to inventions in general?

After reading Sir James's remark, it occurred to me that patent records of industrial firms might show something interesting in substantiation or refutation of the statement. Buried in the records of industrial organizations are many data of immense interest if one only makes the effort to unearth them.

Many firms follow the practice of recording inventions made by their scientists and engineers. Usually, a complete description is prepared for company files and for future action. This is known as a patent disclosure. It is these disclosures which will supply much of the data for this paper. The records of three groups have been examined:

1. Engineers and scientists of the Westinghouse Research Laboratories
2. A typical group of design engineers
3. Engineers of a large non-electrical research laboratory

In 1916 a new building was erected to house the research activities of the Westinghouse Electric Corporation. A few of the already existing research personnel were transferred to the new building from the laboratories at the East Pittsburgh Works but by far the larger percentage was gradually built up by recruiting from universities and industry. Invention statistics have been gathered, therefore, beginning with the 1917 records and extending through 1938. In general, also, unless otherwise stated, the results are for those men who were still with the organization in 1938. Only nine of these men were associated with the company prior to 1916. Only those engineers * are included who might reasonably be expected to make inventions occasionally at least. Some of these were on analytical work and their inventions were very few. Recent employees and laboratory assistants who were or routine testing work only are not included: 55 engineers are included in this group.

The design group consisted of a fairly prolific and homogeneous set of engineers in a long established department where new problems were constantly arising. The period covered is also from 1917 to 1938, inclusive. There were 45 engineers in this department but data for only 36 are used since the other nine made no inventions during their period of employment because of the routine nature of their work or inherent lack of inventive ability.

The third group consisted of the present research engineers of a large non-electrical research laboratory. There were 59 men in this group and the period covered is from 1919 to 1939, inclusive. The starting time was two years later than for the other two groups, and to partly compensate this, the time was extended through 1939, one year later than applies for the other two groups. By stopping at 1939 the variabilities due to the war effort are excluded.

Total Patent Disclosures

The curves of Fig. 1 show the average number of patent disclosures per year, as a function of the inventor's age, for 55 engineers of the Westinghouse Research Laboratories. This graph covers the whole period of service for each man since 1917. Of course, most of the men considered came to the Laboratories subsequent to 1917.

It will be understood that during the period of his employment, each man's inventive output is included for each year of his age. If man A was 35 years old in 1920, B, 35 in 1925, and C, 35 in 1930, the inventions per man-year for age 35 would be the sum of A's inventions in 1920, B's in 1925, and C's in 1930, divided by three (the number of men considered).

It will be seen that for this group inventive genius does not cease at 40, but rather reaches the maximum at 43 years of age. It is interesting to note the gradual and reasonably steady increase in productivity up to that age. There is then a decrease somewhat more rapid than the increase, but even at 59 the curve is above zero. At 43 the increase due to greater knowledge and experience is counterbalanced by decreasing ingenuity or by the changes in type of work, such as from research to executive activities. A second curve on Fig. 1 shows the number of engineers, by age distribution, responsible for the patent disclosures. From this dotted curve it appears that more men apply for patents in their early thirties than at other periods in their life.

Similar data for the group of design engineers is shown in Fig. 2. Here there is a peak at 37 years and another at 42 years, with a rapid dropping off after 44 years. Again, judged by the number of patent disclosures, the most productive years are in middle life.

Comparable results for 59 members of a non-electrical research laboratory are shown in Fig. 3. There is a peak at 30 years, which is rather accidental since it is due to the exceptional output of one man for one year. This exceptional output results from one invention which was split into a considerable number of allied inventions. The

* The term *engineers* includes scientists.

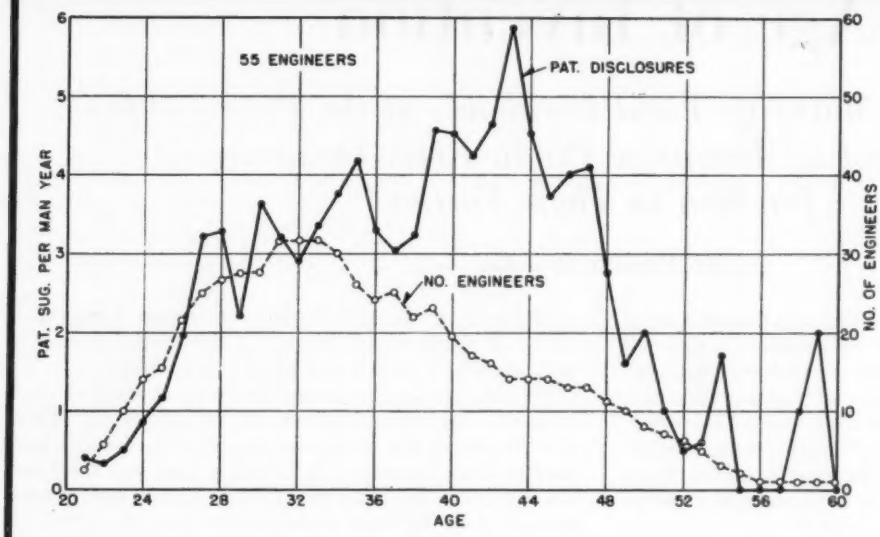


Fig. 1 — Age distribution (light line) and average number of patent disclosures per year, as a function of inventor's age (heavy line) for 55 engineers of the Westinghouse Research Laboratories.

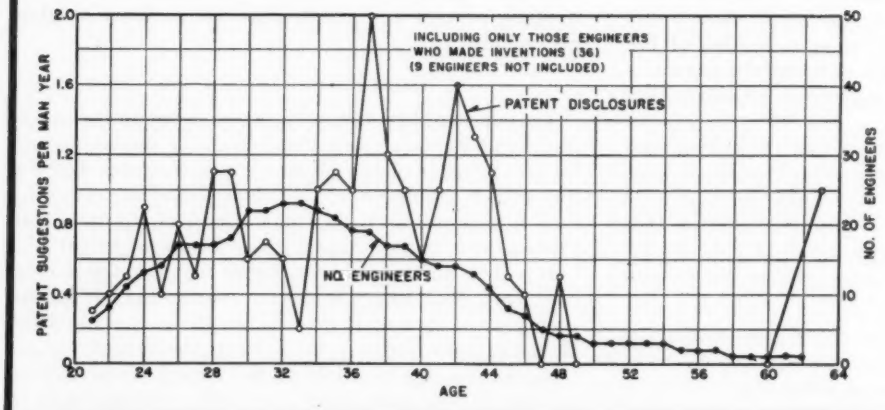


Fig. 2 — For 36 design engineers in the field of electrical engineering, the heavy curve shows age distribution and the light curve indicates the average number of patent disclosures per year for the age of each inventor.

second peak is at 42 years. The high peaks for men in their fifties are not particularly significant, quantitatively, since so few men are involved. They do show, however, that inventive ability does not become atrophied among the older men.

The men in this group were concerned primarily with metallurgical problems. Their inventions are probably best described as discoveries based on controlled experiments. Experience is a large factor in this type of invention and the age limits would naturally be considerably higher than for inventions resulting from a flash of genius.

The combined results for the three groups are plotted in Fig. 4 which gives a truer picture than the first three diagrams, since the results apply to a larger and therefore more representative group. The highest peak of patent disclosures is at 43 years, with the second highest peak at 47 years. The rapid rise up to 27 years and the rapid falling off after 48 years should be noted. The gradual rise from 27 years to 47 years is also significant.

Prolific Inventors

It is instructive to consider the inventive output of certain individuals who are either prolific inventors, or whose inventions have had great commercial value. One engineer is in a class by himself, both as to number of patent suggestions and also as to the commercial value of his patents. It is interesting to note also that he was trained as a mathematical physicist, which makes his record all the more remarkable or significant. Even at 48 his productivity is higher than that of any other man at any age. While his peak output was reached at the age of 27, which is uncommon, his patent productivity has remained nearly constant and very high from age 34 to 48.

Another man had a very low output up to 32 years of age but for the next several years has shown a steadily increasing rate of invention.

A third engineer is interesting. Due to a change of work and added executive responsibility, his inventive output gradually decreased to zero. Largely as a result of a second change, to more nearly his original status, this man's inventiveness at the age of 46 returned to nearly its former high value, and has since been sustained.

Another engineer is responsible for some very useful development work which was long and laborious and resulted in comparatively few patents. A few of these, however, were quite valuable. He reached his peak of productivity at 47.

An individual's inventive output often shows a number

of peaks and valleys with the years. These are the result of changes in status of major activities. After a burst of invention, an engineer often must pause and consolidate his ideas by intensive development leading toward commercialization. During such periods, invention may become temporarily dormant.

An examination of the age for maximum productivity for a group of prolific engineers is interesting. The records of 22 of the more prolific inventors in the three groups of men were studied and the results plotted in Fig. 5. Each block corresponds to one inventor. When two equal maximum values occurred at different ages, one-half was assigned to each age which accounts for the four half heights or square blocks. One man with a maximum at 30 years also had productivity values as high at 42, 43, and 44 years. The concentration at 43 years is, of course, accidental since these maxima might just as well have occurred at ages slightly removed from this value. Each of the three groups of engineers shows high productivity values at 43 years of age. It is interesting to note that just as many maxima occur above the 39–40 point as below.

The genius type of inventor is perhaps more likely to reach his highest productivity at an early age, whereas the normal engineer will reach his best output toward the middle of his career.

Effect of Economic Conditions

A study of patent suggestions as a function of the calendar year is instructive. Some data which apply to all of the Westinghouse research engineers for each particular year are given in Fig. 6. It will be remembered that the data for the previous curves applied only to those men who were on the employed roll in 1938. The curve showing the patent suggestions per engineer per year is the most significant. In 1917, the staff consisted of a few carefully selected men of the scientific type who were full of enthusiasm and ideas. Their patent suggestion productivity was quite high. Later their time was spent in working out the details of their inventions and this required additional men to do work of the more routine type. While the total patent suggestions remained about constant, the number of patent suggestions per man decreased in the few years immediately following the organization of the Westinghouse Laboratories. Later, as the engineers gained more experience and contacts, the patent suggestions (both total and per man-year) increased until 1922. It will be remembered that in 1921

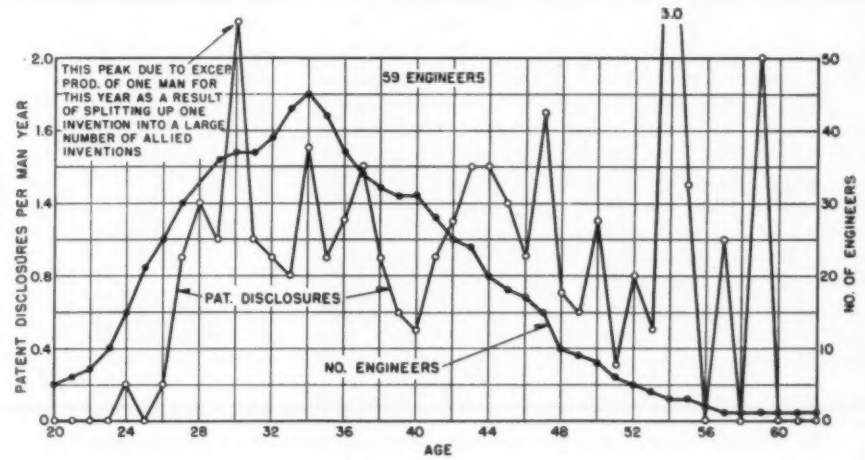

THIS PEAK DUE TO EXCEP PROD. OF ONE MAN FOR THIS YEAR AS A RESULT OF SPLITTING UP ONE INVENTION INTO A LARGE NUMBER OF ALLIED INVENTIONS
59 ENGINEERS
PAT. DISCLOSURES
NO. ENGINEERS
PATENT DISCLOSURES PER MAN YEAR
NO. OF ENGINEERS
AGE

Fig. 3 — For 59 members of a non-electrical research laboratory, the age distribution and the average number of patent disclosures each year are given by the heavy and light lines, respectively.

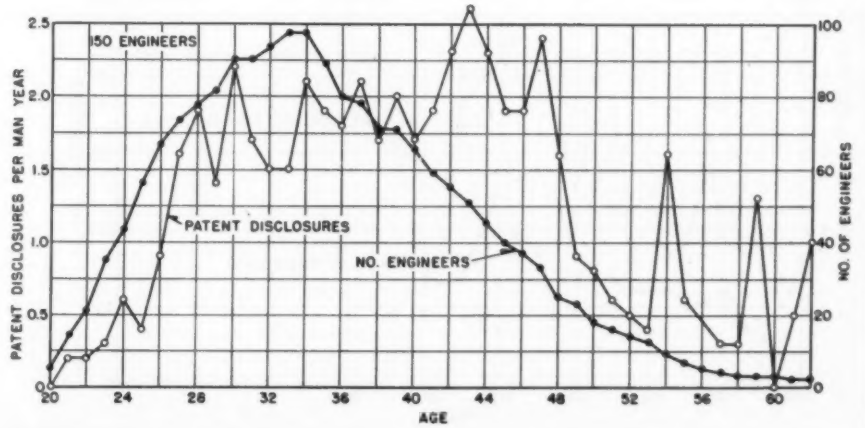


Fig. 4 — A composite study of the data given in Figs. 1, 2, and 3 for 150 engineers making patent disclosures. Since a larger number of persons is involved, the data given here are regarded as more typical than that given in previous figures.

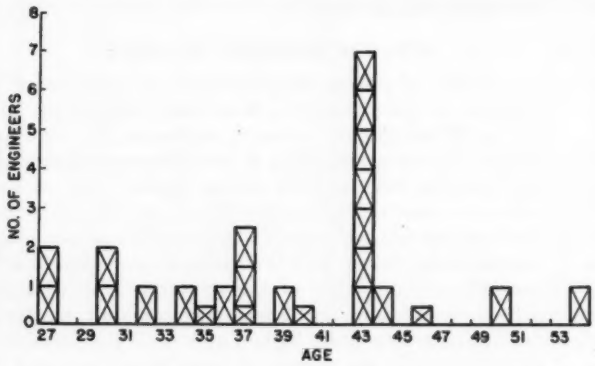


Fig. 5 — Age for maximum inventive productivity, determined from a survey of 22 prolific inventors. Although the sample is a small one, there are indications that the peak of inventiveness is reached by mature men with considerable experience.

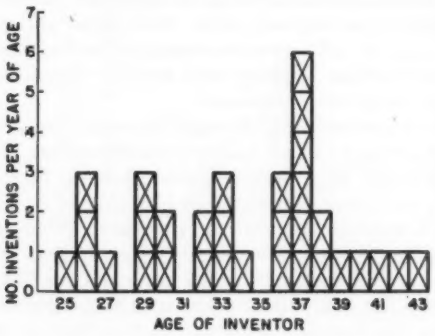


Fig. 7 — Age distribution of engineers of the Westinghouse Research Laboratories making important patent disclosures. The age is that at which the major invention was conceived.

there was a moderate depression, and, as a consequence, a few of the less promising research men were released, as shown by the curve marked "No. of Engineers." This was the first depression experienced by this group of men and it had an effect on their output of new ideas.

The picture for the big depression is different. Most people had become so optimistic in 1929 that they couldn't believe the depression would last. The realization came so gradually that there was no psychological upset among the research engineers and when finally business conditions forced drastic reductions in personnel, the more productive men were not much concerned since they knew that the reductions would only apply to the younger and less productive men. Consequently, there was no considerable change in the number of patent suggestions per man from 1929 to 1933. In fact, during the greatest reductions in personnel — between 1932 to 1934 — the rate of patent suggestions increased very considerably, since the more productive men continued at about normal rate. In general, the decrease in total number of patent suggestions approximately paralleled the decrease in personnel. In 1935 and 1936, however, there was a feeling of pessimism which was reflected in a considerable decrease in productive output, as shown by the dotted curve of Fig. 6. It is evident that in 1938 optimism had been restored and the rate of production of new ideas is very high.

The reduction in patent suggestion with rapidly increasing personnel in 1926–1928 parallels the reduction in 1917–1920, probably for the same reasons. The upswing in 1929–1930 is due largely to an active group in the rapidly growing electronic field; much fundamental work in television was done at this time.

Important Inventions

It might be conceded that the older men still had many new ideas, but the value of these ideas might be questioned. There are some data available on this also. A list

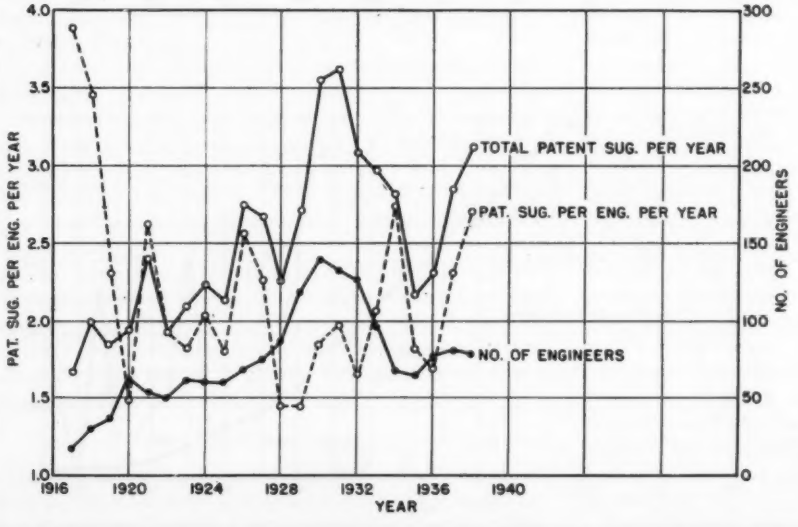


Fig. 6 — A study of patent suggestions as a function of calendar year illustrates the effect of general economic conditions. Observe that the curve of patent suggestions per inventor rose during the depression although the total number of disclosures and the total number of engineers fell during the same period

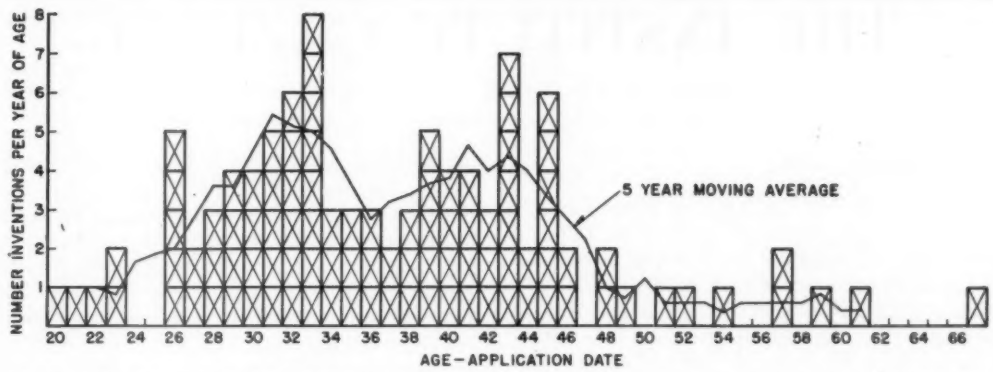


Fig. 8 — Age of inventor at time of filing patents, for 100 men making outstanding inventions in the United States. Each block represents one inventor's age at the time of invention. The line representing the five-year moving average is more informative than the block diagram. Data for this study cover a relatively long period, including that for which technology was not so highly specialized and well organized as it is at present.

of what we believe to be the more important inventions coming from engineers of the Westinghouse Laboratories was compiled, together with the date of conception. The age of the inventor was then determined and the results of this study are plotted in Fig. 7. The peak productivity occurred at 37. There was then a sharp falling off with no important inventions after 43, although up to that point there was one important invention per year. This data probably does not mean that important inventions stopped at this point. The curve will doubtless change shape and be extended into the older age groups some years from now. It takes from five to ten years, and often more, between the conception of an invention and the return of dividends. It is probable that inventions have been made by the older men which later will be found to be valuable, but are not yet recognized as such. This particular group of men is a comparatively young one and the picture which Fig. 7 indicates should change with time. It is highly improbable that the valuable inventions will cut off sharply at 43.

Outstanding Inventions Made in the United States

The *World Almanac* presents a list of the most important inventions made by residents of the United States. An analysis of this list is most instructive. The latest patent issue date given is 1939. One may easily disagree with the choice of some of the inventions, but the list is probably the best available, and for statistical purposes is quite satisfactory. Wherever possible the age of each inventor at the time of making the invention was determined. The filing dates were assumed to correspond closely with the date of conception and it, rather than the date of issue, has been used in this study. On the basis of a number of spot checks it seemed that, on the average, the filing date was one year earlier than the date of the invention up to about 1905 and from then on approximately two years earlier. Therefore, unless the actual filing date was known, it was assumed that before 1905 the date of conception preceded the date of issue by one year, and subsequent to 1905 by two years. A notable exception was the Selden patent in which case the application date was 1879 and the issue date was 1895.

Birth dates of the inventors were found for exactly 100 of these inventions and the inventors' ages corresponding to the application dates were computed. These were assumed to be the inventors' ages at the time of invention. These data are summarized in Fig. 8. The five-year moving average tells the story better than the blocks. There is one peak at 31–33 years and another nearly as high at 41–43 years. More than (*Continued on page 52*)

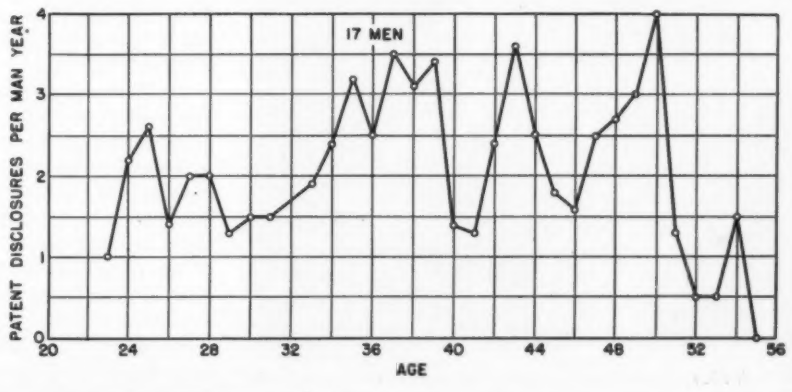


Fig. 9 — Patent disclosures made by 17 Westinghouse department managers and section heads. This study illustrates that the inventiveness of executive engineers is maintained throughout middle life.

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Heads Civil Engineering

JOHN B. WILBUR, '26, professor of structural engineering, has been appointed head of the Department of Civil and Sanitary Engineering, according to a recent announcement by Thomas K. Sherwood, '24, Dean of Engineering at the Institute. Professor Wilbur has been acting head of the department since June, 1944, following the death of Theodore B. Parker, '11, its head at that time.

A native of Oakland, Maine, Professor Wilbur was educated at the Academy High School in Erie, Penn., and the Institute, from which he was graduated in 1926. He was awarded the degree of master of science in 1928 and his doctorate in 1933. Professor Wilbur served as an assistant in his department from 1926 to 1928 when he joined the engineering staff of the Maine Central Railroad Company. From 1929 to 1930 he was a bridge designer for the New York Central Railroad Company in New York. In 1930 Professor Wilbur returned to the Institute as an instructor in civil engineering and was promoted to the rank of assistant professor in 1934. He was appointed an associate professor in 1937 and professor of structural engineering in 1943.

Professor Wilbur was responsible for the development of the structural analysis laboratory which was established at the Institute in 1936. In 1934 he developed and built the simultaneous equation calculator — a computing machine which solves nine linear simultaneous equations.

Photo by Fabian Bachrach

John B. Wilbur, '26, takes on new duties as head of the Department of Civil and Sanitary Engineering.

Professor Wilbur has had wide experience as a structural engineer and was associated with the firm of Fay, Spofford and Thorndike on the design of the Lake Champlain Bridge, as well as the continuous truss highway bridges over the Cape Cod Canal at Bourne and Sagamore. He has done important consulting work for various engineering and insurance companies. From 1940 to 1945 he was chief engineer for the Smith-Putnam Wind Turbine project in Vermont for the S. Morgan Smith Company.

During the war he was a consultant to the National Defense Research Committee and was in charge of an investigation dealing with the constructural design of fortifications conducted at the Institute for the Office of Scientific Research and Development.

Professor Wilbur is a member of the American Society of Civil Engineers and of the Boston Society of Civil Engineers, and has twice received the designers section award of that society. In 1943 the society presented him with the Desmond Fitzgerald award. He is also a fellow of the American Academy of Arts and Sciences, a member of the American Society for Engineering Education, Sigma XI, and an honorary member of Chi Epsilon, the honorary civil engineering fraternity.

He is the author of many technical papers and bulletins, and with Professor Walter M. Fife, of a textbook, *Theory of Statically Indeterminate Structures.*

In 1926 Professor Wilbur married Miss Lillian E. Kelley of Oakland, Maine. They have one son.

Arthur Dehon Little Memorial Lecture

SIR EDWARD V. APPLETON, distinguished English physicist and Secretary of the British Department of Scientific and Industrial Research, will deliver the first annual Arthur Dehon Little Memorial Lecture at the Institute on November 19. Sir Edward has chosen for his subject: "Science, Government, and Industry."

The lectureship was established by the firm of Arthur D. Little, Inc. in honor of the memory of Arthur D. Little, '85, whose interest in research for industry led to many notable contributions.

Sir Edward is internationally known for his studies of the properties of the upper atmosphere which resulted in proof of the existence of ionized layers, one of which was given the name of the "Appleton layer." It was in 1925 that Sir Edward established the existence of ionized layers. This knowledge led to developments in the technique of radio-location and an understanding of the principles of the propagation of radio waves that has made it possible to predict the best frequencies for radio transmission in any part of the world at a given time.

Sir Edward was born in Bradford, England, in 1892 and went from the Hanson School to St. John's College, Cambridge. He took parts I and II of the Natural Science

Tripos in Physics in 1913 and 1914, a period in which he also read geology and was the Wiltshire Prize man in 1913. In 1920 he returned to scientific work at the Cavendish Laboratory of Cambridge University as assistant demonstrator in experimental physics, and was appointed a sub-elector at Trinity College in 1922. From 1934 to 1936 he held the professorial appointment of Wheatstone Professor of Physics at King's College, University of London, following which he was appointed Jacksonian Professor of Natural Philosophy at Cambridge University and became a fellow at St. John's College.

The Royal Society of London elected him a fellow at the age of 35, and in 1933 he was awarded the Hughes Medal of the Society. He was awarded the Morris Liebmann memorial prize in 1929 and was elected Vice-president of the Institute of Radio Engineers in 1932.

In his post as Secretary of the Department of Scientific and Industrial Research, Sir Edward directs research in all branches of natural science and their application to industry except in the fields of medicine and agriculture, which are handled by separate departments. The divisions of his department include research in building, forest products, fuel, roads, water pollution, and geological surveys.

Librarian Designee

VERNON D. TATE, Director of Photography, in charge of the Photographic Records Office of the National Archives, has been appointed librarian designee at the Institute according to John E. Burchard, '23, Director of Libraries. He will assume his duties at the Institute on January 1, and will become librarian on July 1, 1947, upon the retirement of William N. Seaver who has served as Institute librarian since 1925.

Born in Mt. Carmel, Ill., on January 3, 1909, Mr. Tate spent most of his boyhood in Arkansas, Washington, and California. Undergraduate work was begun at the University of California in Los Angeles in 1925, and graduate work on Pacific Coast maritime history was begun at the same institution in 1929. In the spring of 1930, Mr. Tate was awarded the Native Sons of the Golden West traveling fellowship in Pacific Coast history. The next two years were spent in research at the Archivo General de Nacion, and in the archives and libraries of the several educational institutions of Mexico City, Guadalajara, Tepic, Puebla, and Oaxaca. During this period, Mr. Tate was engaged by the Library of Congress to reproduce materials for the history of the United States in the principal archives of Mexico, and developed early techniques for microfilm documentation. As a result of his work in Mexico, Mr. Tate accumulated some 75,000 pages of original documentation in the then new and novel form of microfilm. During 1933 and 1934 Mr. Tate was Teaching Fellow and Research Fellow, respectively, at the University of California, and received his doctorate in 1934.

In 1934 Dr. Tate spent the year in research and microphotography in Washington, D. C., and when the National Archives neared completion, was given charge of all of the duplicating and photographic reproduction activities of the agency. He established three photographic laboratories to preserve and perpetuate the holdings of the National Archives. One was for general photography and still work, another for motion picture photography, and the third for sound studio and sound records of all types. In directing the activities of these laboratories, Dr. Tate engaged in basic research in two fields; the application of photographic techniques to archival and library problems, and research in subject fields employing these techniques.

For two years during the war he was assigned to the Naval Command of the Office of Strategic Services, and in his laboratory at the National Archives engaged in technical research and production on war subjects, working directly for the Joint Chiefs of Staff.

Dr. Tate edited the *Journal of Documentary Reproduction* between 1938 and 1942 and has been an associate editor of *Neptune*, a periodical devoted to the maritime history of the Western Hemisphere.

Dr. Tate's broad and widespread experience in modern library techniques fits him admirably for the position of librarian of the Charles Hayden Memorial Library, where, as recorded on page 25, every effort will be made to advance true scholarship and culture by the most effective means available.

Fantastic Figures

AT the last gathering of the season, 92 members and guests attended the 251st meeting of the Alumni Council held, as usual, in Pritchett Hall, Walker Memorial, on May 27, with A. Warren Norton, '21, presiding.

First order of business called for introduction of newly elected officers of the Alumni Association, and new members of the Alumni Council. President Norton announced that newly elected officers to serve for one year are Alfred P. Sloan, Jr., '95, Honorary President, and Harold Bugbee, '20, President, and, for a two-year period, George

Vernon D. Tate, in charge of Photographic Records Office of the National Archives, will become librarian.

C. Dandrow, '22, Vice-president. Elected to serve as members of the Executive Committee for a two-year period are Larcom Randall, '21, and Avery A. Ashdown, '24.

Results of Alumni voting gave elections to the following: Term members of the Corporation for five years, A. Warren Norton, '21, Frederick S. Blackall, Jr., '22, Albert J. Browning, '22; members of the National Nominating Committee for District 1, Robert S. Williams, '02; District 2, Robert C. Erb, '17; District 4, Ralph C. Robinson, '01; District 5, Gordon G. Holbrook, '10. Class representatives elected are: C. Frank Allen, '72; George W. Kittredge, '77; Charles E. Fuller, '92; John P. Ilsey, '97; Frederick H. Hunter, '02; George A. Crane, '07; John M. Pettingell, '12; H. E. Lobdell, '17; C. Yardley Chittick, '22; Dwight C. Arnold, '27; Thomas E. Sears, Jr., '32; Philip H. Peters, '37; and Warren S. Loud, '42.

Speaker of the evening was Horace S. Ford, who gave an illustrated talk on expansion of M.I.T. activities since the Institute moved to its present Charles River site. Operating income of the Institute, exclusive of war research was $750,000 in 1916, $2,800,000 in 1926, $3,700,000 in 1940, $4,400,000 in 1945, and it is estimated to be $5,000,000 for 1946. When war income is included these figures become fantastic; total income was $6,000,000 in 1940, $12,000,000 in 1942, $20,000,000 in 1943, $25,000,000 in 1944, $40,000,000 in 1945, and $25,000,000 in 1946, with an estimate of $10,000,000 for 1947. The growth of staff has been from 600 in 1940 to 700 in 1946, but non-staff personnel increased from 800 in 1940 to a peak of 6,067 in 1945 and the estimate for next year is 2700. In 1916 there were six administrative officers. Today there are 50 administrative officers and there is distributed among them much more than 10 times the amount of work there was to be done in 1916.

Present and anticipated changes in plant were also discussed. Since the war, the Institute has acquired a permanent building for chemical engineering, originally built for Chemical Warfare Service, and one of the permanent Radiation Laboratory buildings. A temporary war research building will be used as barracks to accommodate 600 unmarried students. Westgate village is now housing 100 married couples, and plans are underway for additional quarters to house 200 more families.

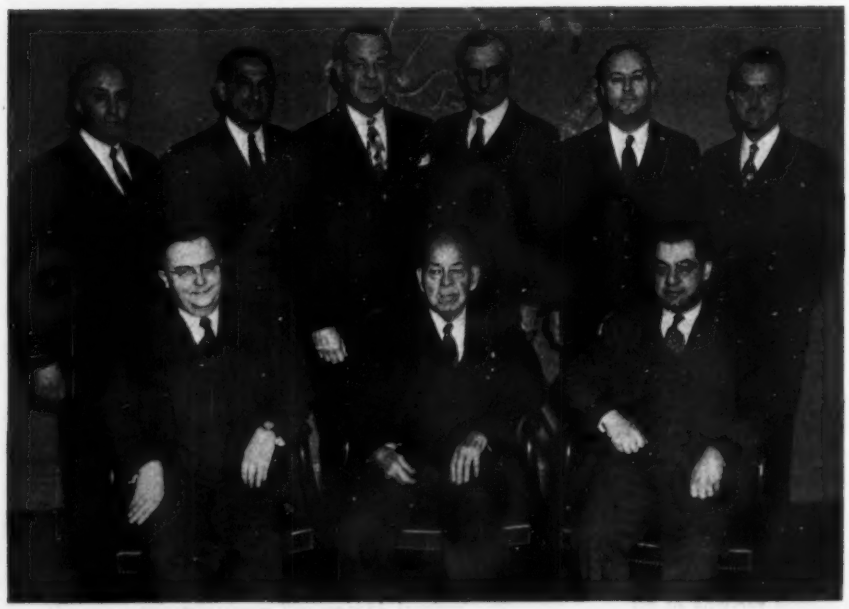
Increased Investment

AN increase of one hundred dollars per academic year in tuition at M.I.T. has been announced by President Karl T. Compton, this increase to take effect with the opening of the summer term in 1947. The increase will bring the Institute's tuition to seven hundred dollars an academic year. In making this announcement, Dr. Compton said:

Since 1939–1940, the Institute's operating expenses have risen 28 per cent and are still rising. The increase in tuition amounts to approximately 16 per cent and thus goes only part way in meeting higher costs. A recent survey of college fees indicated that increases are being made throughout the country and that the average of reported increases has been 19 per cent. Although the Institute's expenses, particularly for technical equipment and extensive laboratory operations in the various professional fields, are higher per student than are those at many other institutions, its comprehensive tuition fee includes all the charges usually imposed as extra undergraduate fees, such as athletic, medical, matriculation, and diploma fees.

Except for alloting increased funds to scholarships, we shall apply the additional income received mainly to salaries and wages. While substantial increases in compensation have already been put into effect at the Institute, we believe that further increases must be made if our personnel are to be adequately protected against the rise in the cost of living and if we are to be able to secure and hold outstanding teachers. Even with the increase in tuition, the student will be paying only about half the cost of his education, the rest being met by income on endowment.

In recent years we have received many additions by gift and bequest to our scholarship funds, and these funds, supplemented by allotment from the increased fees and by the Technology Loan Fund, will be ample to meet any increased needs for student aid resulting from the higher tuition. The Institute has a student loan fund totaling (*Continued on page 46*)



A group of Honorary Secretaries in Chicago at a recent meeting on scholarship. In usual reading order are: (seated) H. E. Lobdell, '17, Dean of Students, Lonsdale Green, '87, T. P. Pitré, Associate Dean of Students; (standing) Ralph Sargent, '18, William Steinwedell, '25, Sherry O'Brien, '17, Louis H. G. Bouscaren, '04, Robert W. Van Kirk, '18, and Edmund G. Farrand, '21. Unavoidably absent were Donald B. Gilman, '32, and Arthur B. Brand, '26.

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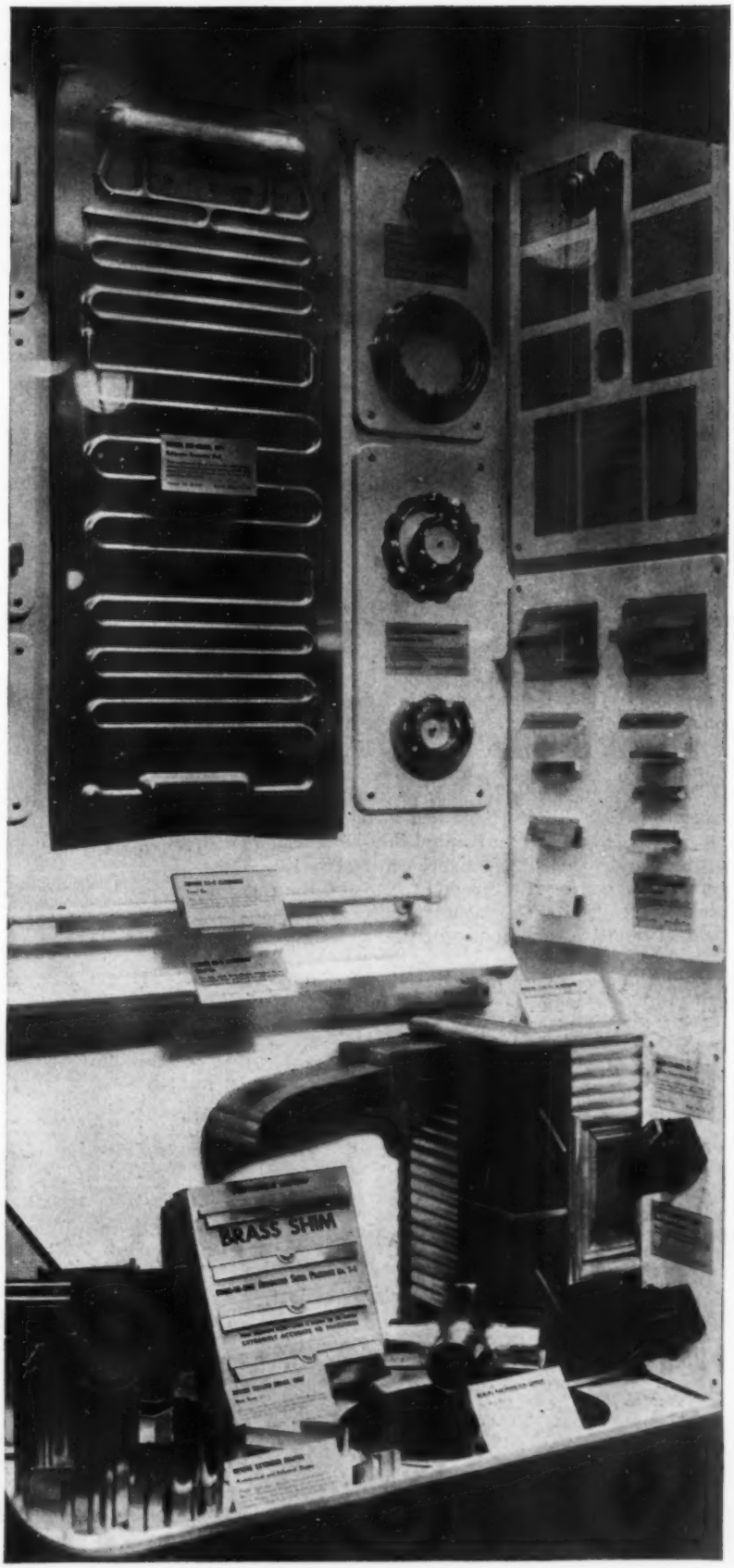

THE INSTITUTE GAZETTE

(*Continued from page 44*)

$1,800,000 which has now been in operation since 1930 and from which loans are made at a two per cent interest. At no time has the demand on this loan fund exceeded $900,000 so that here again we have an ample margin to insure that students who are scholastically qualified can obtain adequate assistance.

In his announcement President Compton spoke also of the Administration's determination to adhere to the ideal of continually maintaining Technology as one of the institutions in a position of independent leadership in science, engineering and architecture. He emphasized the importance of this ideal in view of trends whereby the financial burden of higher education seems destined to be more and more assumed by governmental agencies. Dr. Compton stated:

> It is becoming increasingly important that a certain number of private and independent educational institutions should maintain positions of unquestioned leadership and thus set standards of achievement and freedom for all higher education.

Industrial Relations Appointee

JOSEPH N. SCANLON, Director of Research and Engineering of the United Steelworkers of America, C.I.O., and widely known for his contributions to the improvement of labor-management relations, has been appointed a lecturer in the Department of Economics and Social Science at the Institute, James R. Killian, Jr., '26, Vice-president, announced recently.

"It has often been suggested," said Dr. Killian, "that educational institutions must help to educate labor leaders. It has less often been realized that labor leaders with a wide background of experience can be effective educators. In appointing Mr. Scanlon to its staff the Institute seeks to broaden its educational facilities in the important field of industrial relations with the object of bringing about a better understanding of the problems of union-management relations."

Mr. Scanlon, a native of Cleveland, Ohio, has been actively associated with the labor movement since 1935, as a member of the Amalgamated Association of Iron, Steel and Tin Workers, which was later merged with the Steelworkers Organizing Committee. Mr. Scanlon began his career as a cost accountant and, after considerable experience with fabricating companies and a well-known firm of cost accountants, he took a position in the basic steel industry. After several years' experience with cost accounting he went to work in the production department of the steel industry where he served as a supervisor, production and maintenance worker in almost every department of steel operations.

He joined the staff of the United Steelworkers of America in 1940, and devoted most of his time to the development of union-management co-operation plans with many firms. He was a member of several labor advisory committees of the War Production Board during the war and is now a labor member of the National Steel Commission.

Mr. Scanlon is widely known as a speaker and has frequently addressed meetings of employers, trade associations, and engineering societies on problems of labor relations. He has also lectured and participated in industrial relations seminars and conferences at Harvard, Princeton, the Universities of Pennsylvania and Chicago, and Holy Cross College, as well as at the Institute.

Metallurgy Report

A MEETING of the Visiting Committee on the Department of Metallurgy * was held in Cambridge on October 9, 1945. The Committee first visited the various laboratories of the Department headquarters and listened to statements from key men on (*Continued on page 48*)

* Members of this Committee for 1945–1946 were Louis S. Cates, '02, Chairman, Archer E. Wheeler, '95, Harold B. Harvey, '05, Flemmon P. Hall, '21, Carl M. Loeb, Jr., '28, Galen H. Clevenger, and Willard H. Dow.

Roger Willcox, '42, skipper, John F. Fennessey, 2–44, crew, and Walter C. Wood, '17, recently returned to the Institute as sailing master, with national 110-class championship trophies won at Larchmont, N. Y. on August 16. Fleets from Marblehead, Detroit, Chicago, and New York were represented at the regatta, which marks the first time the Technology club has contended and taken honors outside the intercollegiate class.

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The right thing in everything men and boys wear

(*Continued from page 46*)

the staff who outlined the present situation in their own divisions and suggested future needs. The men interviewed were Professors John Chipman, Morris Cohen, '33, Antoine M. Gaudin, Victor O. Homerberg, '21, Frederick H. Norton, '18, John T. Norton, '18, and John Wulff.

At the conclusion of these interviews the Committee adjourned for lunch with James R. Killian, Jr., '26, and Robert M. Kimball, '33, of the Administration; and Professor Robert S. Williams, '02, and Carl F. Floe, '35, of the Department. An active but informal discussion of Department problems followed. General agreement was reached on the following points:

The equipment of many laboratories needs to be modernized and rearranged for more efficient use of space. In some cases additional equipment for routine instruction is required as well as space to handle large classes properly. The cost of this modernization, rearrangement, and re-equipping of all laboratories was estimated by the staff to require about $250,000.

The Committee recognized the need for the development of instruction, and especially of research, in mechanical metallurgy (forging, rolling, pressing, wiredrawing, and so on) for which no facilities are now available in the Department. It was the unanimous feeling that a new building and extensive equipment for this purpose were not justified, for two reasons: (a) the great difficulty of collecting the large capital sum necessary for this addition to the Department; and (b) the great cost of operation and maintenance if large-scale equipment were to be installed. It was felt that the Administration should make every effort to effect a satisfactory working arrangement with the Department of Mechanical Engineering, in which much of the equipment needed is now available or its purchase is contemplated. It was the unanimous feeling that duplication of expensive equipment in all divisions should be avoided if at all possible.

It was recommended that a staff member be added to specialize in the field of the corrosion of metals.

Methods of obtaining industrial fellowships or grants-in-aid in order to increase the amount of research in the Department were discussed but were left for consideration at a later meeting of the Committee.

The re-establishment of work in electrochemistry and electrometallurgy was considered at some length. It was the general agreement that adequate training in electrometallurgy must be given but no decision was reached as to whether this should be treated as an independent subject or included in the general work in production metallurgy.

Survey of Electrical Curriculum

FOR the Department of Electrical Engineering a meeting of the Visiting Committee* was held in Boston on January 21, 1946. Each year, the Committee has been furnished a review of the Department's activities and the problems which it is facing. The report this year was particularly helpful, and the Committee appreciated the time and effort given by the Department in so clearly presenting the facts.

The morning was spent in a visit to the laboratories, particularly the Laboratory for Insulation Research, the Center of Analysis, the Servomechanisms Laboratory, the Research Laboratory of Electronics, the Stroboscopic Photography Laboratory, and the High-Voltage Research Laboratory. The breadth, scope, and character of the work undertaken in these various fields impressed the Committee. The results obtained not only made tremendous contributions to the war effort but, in addition, opened up new fields which promise much for the future in peacetime. Important as these things are, the Committee was impressed with the character, intelligence, imagination, and ability of the men in charge of these groups, under whose influence and direction the graduate and undergraduate will be trained.

The Department's present enrollment makes it the largest Department at the Institute, and, by reason of the interest in electronics and communication emphasized by the war, it has a high percentage of new enrollment. This presents a substantial problem for the staff, which will require additions (particularly of instructors, research associates, and assistants) in order to care for the emergency student registration of veterans, to reinstate some part of the educational development and provide time for creative activity on the part of the staff, and to man the greatly augmented research activities of the Department.

The discussion in the afternoon was directed largely to the educational program, particularly in the power field. The need for additional space for the considerably expanded Department was also discussed.

The Committee gave considerable time to a discussion of the desirability of thorough grounding in the broad fundamentals as contrasted with narrower instruction in specialized branches of electrical engineering work. The Committee was unanimous in feeling that, while certain courses in specialized knowledge are necessary, the greatest emphasis should be placed on the broader, rather than the narrower, specialized training. Without attempting to outline the various arguments which were advanced, it was generally agreed that the importance of servomechanisms should be stressed because of the broad overall mental development which such study embraces.

The Department has insisted that thermodynamics be included in all course options, with student choice allowed as to whether the mechanical engineering, chemical engineering, or physics approach be selected. In the field of mechanics, no substitutions have been allowed, since past experience has shown that students (particularly for those transferring to the Institute) have been weak in these subjects. In two of the three options in the Electrical Engineering Course, some form of fluid mechanics is required.

The Course, therefore, requires a degree of study in mechanics, which in the opinion of the Committee, is essential. It was not considered necessary to include a larger number of mechanical engineering subjects but the Committee felt that more emphasis, and possibly more time, might be given to these subjects in the undergraduate years — that added emphasis might well be placed on more instruction in the broad (*Concluded on page 50*)

* Members of the Committee for 1945–1946 were: Francis J. Chesterman, '05, Chairman, Harold B. Harvey, '05, Philip H. Chase, '09, Reginald L. Jones, '09, Robert E. Doherty, F. C. Lindvall, and Harry C. Wiess. Also present were Edward L. Moreland, '07, Executive Vice-president, Carlton E. Tucker, '18, and Harold L. Hazen, '24, of the Department, and Arthur H. Kehoe.

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THE INSTITUTE GAZETTE

(Concluded from page 48)

field of applied mechanics. At the graduate level, the work in servomechanisms, transients in linear systems, and vibrations apparently provide sufficient emphasis in the broad field of mechanics.

With so many of the students interested at the present time in radar and electronics, it was felt that the Department would be well advised to emphasize the value of a thorough grounding in fundamental education, incorporating in this training the newer developments as illustrative examples, rather than as specialized fields of major interest.

For some years students have not been attracted to the option in electrical power to the extent which this important field seems to justify. Since the beginning of the war this decline has been increasingly apparent. In an attempt to further stimulate student interest in this important professional field, and provide a more equitable distribution of students in each option, the Department may follow either of two courses. It could take steps to revise the Course by putting additional emphasis on the newer phases, such as the electric-power problems of the airplane, the power problem involved in controls, and the many small special-purpose highly engineered motors and generators, or it could continue along the lines which it has been following, with such normal additions to the subjects in the electrical power field as are needed. The two members of the Committee representing the power field discussed the various problems at some length, and the conclusion of the Committee was that the Department should not attempt to change the scope of the electric-power program by a complete revision of the Course or by the employment of a leader in that professional field. Although student interest in the power option is diminishing, the Committee believes the staff should include one or two men who are strong in the field of electric power.

Adequate space is an ever-present problem and one which must be especially recognized in view of the newer phases of electrical engineering.

Research Appointment

ORIGINATOR of a compact and efficient vacuum still to produce fresh water from sea water, as recorded on page 155 of the January, 1946, issue of The Technology Review, Dr. Robert V. Kleinschmidt, '18, has been appointed a research associate in the Institute's Department of Mechanical Engineering, to aid in gas turbine research.

Dr. Kleinschmidt was recently released from active duty in the Navy with the rank of Commodore. His war activities covered the development of new types of fuel plants for naval vessels of all types and brought him into a position of leadership in the field of gas turbine design. His thesis for his D.Sc. degree at Harvard in 1923 embraced some of the first extensive measurements of the properties of high-pressure superheated steam. Since that time he has served as consulting engineer in applied thermodynamics. He has been associated with Arthur D. Little, Inc. for many years and has at various times been associated with important industrial firms in this country.

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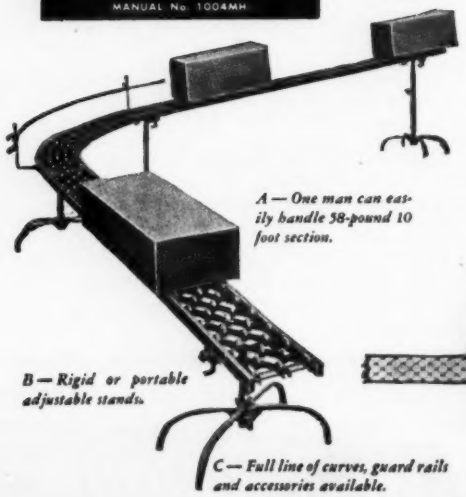

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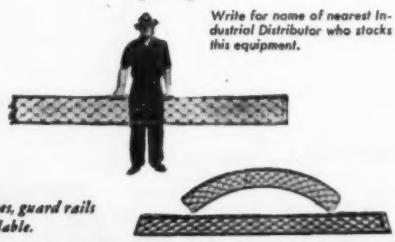

LOAD-LIFTS
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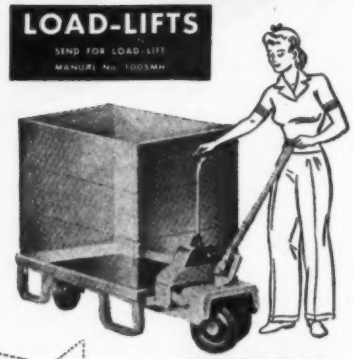

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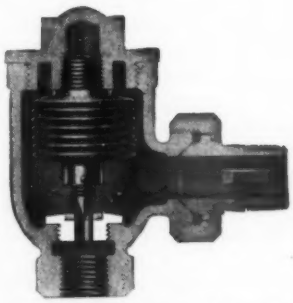
MARKET FORGE COMPANY MATERIALS HANDLING DIVISION 99 GARVEY ST., EVERETT 49, MASS.

This Webster System served 23 years with practically no Radiator Trap repairs

HOTEL BELLERIVE, KANSAS CITY, MO.
Built in 1922. Architect, Preston J. Bradshaw, St. Louis.
Owner, Barney Goodman. Operated by Beacon Rental Co.

This is the story of 605 radiator traps — and how they served for 23 years with practically no repairs.

In selecting equipment for the Hotel Bellerive in 1922, Architect Preston J. Bradshaw, of St. Louis, sought long life and low maintenance cost. He specified Webster Sylphon Traps for which the contractor paid $3.68 each.



WEBSTER SYLPHON TRAP
Originally installed in Hotel Bellerive. Darker portion shows replacement made after 23 years service.

For 23 years, heating comfort was unimpaired and this building required only 24 new radiator trap interiors—one per year.

They might have bought traps at $2.00. But, what happens to economy when such a trap becomes inoperative? Add 90 cents for new interiors at five-year intervals and you would have a trap cost of $5.60 to date compared with $3.68 for the best available equipment.

Also important is the trouble-free heating service provided by Webster Equipment—the avoidance of heating complaints which might have meant added indirect cost — even loss of rental income.

FRED N. SCHAAD Webster Representative in Kansas City. Schaad moved to Kansas City from Columbus about a year ago after having been a Webster Sales and Service Representative in the Ohio capital for 18 years. He is typical of the men who make possible Webster's service to customers.

During the 1944-45 heating season a complete check-up and overhaul of all traps was begun by the Hotel Bellerive. Replacement of worn interiors with genuine Webster Sylphon Attachments, each with new bellows, valve piece and insert seat gives the hotel a better trap than the original one because manufacturing processes have improved, bellows are stronger and more uniform, valve piece and seat are now stainless steel whereas in 1922 they were brass.

Of course, this service record of Webster Equipment would not have been achieved without conscientious operation of the heating system at proper low pressures and competent supervision by the rental company. Proper selection of heating equipment *and proper use*—these are both essentials of heating economy.

Are You Planning a 194? Hotel Bellerive?

In 1922, the logical choice was a Webster Vacuum System with Webster Traps on radiators and drip points.

Today the choice would be a "Controlled-by-the-Weather" Webster Moderator System with:

(1) Webster Outdoor Thermostat Control automatically assuring the lowest possible pressure consistent with comfort;

(2) Webster System Radiation — concealed convectors made of copper tubing and aluminum fins, with *integral* Webster Traps and Valves;

(3) Webster Float and Thermostatic Drip Traps on heating coils of air conditioners and drip points of the piping system;

(4) Webster-Nesbitt Unit Heaters for garage space and similar heating zones.

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Nor are we satisfied that ordinary production and inspection methods offer you adequate quality protection . . . we *individually test* each Arnold magnet in a loud speaker structure before shipment.

Another "individual touch" which has contributed to winning industry-wide customer acceptance for Arnold magnets is our established minimum standard of 4,500,000 BHmax for Alnico V material.

Over five million Arnold loud speaker magnets of the R.M.A. type have been produced since V-J Day under these quality safeguards. Continued adherence to them assures you of long-lived, dependable product performance.

In the mass-production of magnets, the Arnold "individual touch" does make a difference. Let us give you the whole story.

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Specialists in the manufacture of ALNICO PERMANENT MAGNETS

AGE OF INVENTION

(*Continued from page 41*)

one-half of the outstanding inventions in this country were made at the age of 36 or more. Thirty-five per cent of the inventions (some of them very outstanding) were made after the inventors had reached 40 years of age. It will be noted that one of these inventions was made when the inventor had reached an age of 67 years. Age 48 appears again as an important peak. In most of the data the beginning of the decline seems to start along here.

Psychological studies and data on the age at which certain inventors conceived their first important ideas have left the impression in the minds of many people that men are most productive of new ideas in their late twenties or early thirties. Such an opinion entirely ignores the effect of gradually increasing knowledge and experience, particularly with reference to those who live in a scientific or technical atmosphere.

No Age Limit for Genius

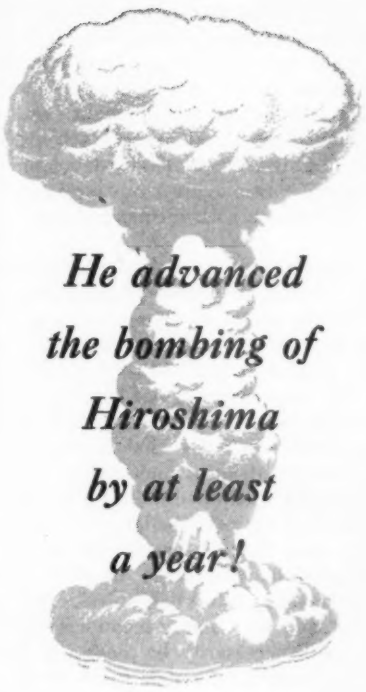
It is believed that these data definitely establish that inventive genius does not cease before 40 years of age but that it continues with great vigor for a number of years longer. For the groups studied, the peak of inventive productivity is reached well after 40, and there is considerable activity even after age 50. The average age of the technical men in the Westinghouse research group was 37 in 1938 and for the other two groups the average was 40 years.

An examination of the data indicates that the period of greatest productivity, as based on the number of patent suggestions, is between 27 and 48 years of age. On the basis of outstanding inventions the greatest productivity is between 26 and 45 years of age. Part of the decrease for the older men is due not to any loss of ingenuity, but results from change in character of their work; many of them get into executive positions and must devote most of their energies to other than strictly technical problems. The results of a study of the patent disclosures made by 17 department managers and section engineers (combined Westinghouse research and design department) are given in Fig. 9. Of course most of these men did not occupy executive positions until they were 35 years of age or more. It is evident that the inventive productivity of these men, representing, of course, a selected group of men with especially vigorous minds, was well sustained until the age of 50, indicating that in spite of their executive duties they found time to consider new ideas with unabated vigor. Actually the highest productivity occurred at 50 years of age.

As men get into more responsible and executive positions some of them may become less active in developing new ideas for machines and physical objects, but their inventive genius may, and often does, turn to new ideas in human relations and to means of dealing with complicated situations which must be adjusted. Of course such mental activity would never appear in a study limited to an examination of patent suggestions.

Another factor in this study, and one which tends to favor the younger man, should also be taken into account; the maturity of judgment of more experienced engineers.

(*Concluded on page 54*)



He advanced the bombing of Hiroshima by at least a year!

This is a "now it can be told" story of wartime research.

It started back in post World War I days when Dr. Harvey C. Rentschler, Director of Research for the Westinghouse Lamp Division, and Dr. J. W. Marden, an associate, decided to determine the melting point of a rare mineral . . . *uranium.*

In his unending search for an improved electric lamp filament, Dr. Rentschler wanted to find out if *uranium* would give better service than *tungsten.*

So Dr. Rentschler and his associates worked for about a year before they found a way to make pellets of pure uranium from which the melting point could be determined. Although uranium's melting point made it unsatisfactory for a lamp filament, Westinghouse continued to supply tiny amounts of the precious metal to colleges and research laboratories for experiments in nuclear physics.

(Little did they realize that their know-how would one day give America a head start in the race towards history's grimmest goal!)

For the most devastating war of all time had meanwhile blazed throughout the world—and scientists in many countries were feverishly trying to discover a method for unleashing the incredible energy concealed within the atom.

Then, early in 1942, Dr. Rentschler received a telephone call. The director of the atomic experimentation project at the University of Chicago wanted to know how soon Westinghouse could supply *three tons of pure uranium*!

Dr. Rentschler and his co-workers immediately went into action. They set up a miniature uranium "factory" in the Lamp Division laboratory—ultimately increasing their production of pure uranium from 8 *ounces to* 500 *pounds daily*, cutting its cost from $1,000 *to* $22 *a pound.*

And within a few months, Westinghouse had supplied *more than* three tons of the vital metal to the Chicago Metallurgical Project Office . . . where the famous "atomic pile" experiments were conducted. They also supplied uranium to physicists at Princeton University who did much to the pioneering work on the atomic bomb.

. . . . . It all started as an obscure experiment to find a *better* lamp filament—like many another quest for product improvement that goes on constantly in the great Westinghouse research laboratories.

But, today, Dr. Rentschler's work of 20 years ago is given full credit for advancing America's atomic bomb activities by at least a year!

Westinghouse

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Tune in: TED MALONE — *Monday, Wednesday, Friday, 11:45 am, EST, American Network*

AGE OF INVENTION

(*Concluded from page 52*)

The older and more experienced engineers are unlikely to turn in inventions which, when less experienced, they might have thought worth-while: in other words, this study may include a number of innovations of younger men which, to a more mature person would not seem sufficiently important to report as a patent disclosure. This might appear to retard the rate of patent suggestions of older men.

Stimulation of Group Research

A group of men working together stimulate each other and knowledge gained in one field is often directly applicable to the solution of a problem in another field. Often a new idea would never occur to an individual except from the impact of other minds on his. Most effective advances in the development of electrical insulation have been accomplished in several research laboratories by bringing together a group of scientists and engineers trained in physics, chemistry, and electrical engineering. The younger and older men in the group stimulate each other's mental progress.

It may be that a study of inventions made by individual workers will indicate a lower age at which inventive ability reaches its maximum. After a man has tried to develop an invention commercially without an organization behind him, he is likely to decide soon that from an economic standpoint invention does not pay. Because of the difficulties and discouragements which beset the free lance inventors, he may turn his energies to other channels, thereby reducing his inventive activities in order to achieve more stable and certain employment. On the other hand, the worker in organized research activities is relieved largely of the burden of commercial development and exploitation and will continue his inventive activities for many years in accordance with his natural bent and abilities.

In contrast to the popular opinion that inventive genius reaches a peak in the early years of manhood and largely dies out before the age of 40, these studies appear to prove conclusively that inventive ability not only does not die out at that age, but under suitable conditions, actually reaches a maximum well beyond that age. Also, although complete supporting evidence is not yet available, there is strong reason to doubt that in the future, the majority of the important inventions will come from scientifically or technically untrained men. In the *World Almanac's* list a large percentage of the later outstanding American inventions were made by men with technical educations and associated with large manufacturing concerns. Certainly the simpler and more obvious inventions have been made, and, in a highly technological era, future contributions will necessarily be made, by those trained to understand and progress in more advanced topics. It is believed, therefore, that the picture given here may be as typical of the future as it is representative of the past.

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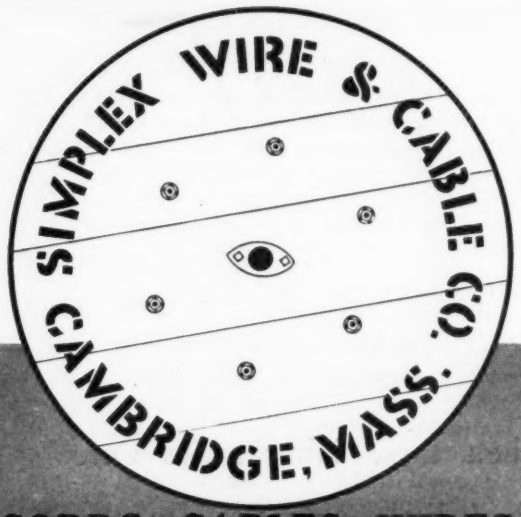

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SUN AND EARTH

(*Concluded from page 36*)

following a given coronal peak is still significantly heightened after one solar rotation plus four days, just as it is after four days.

In the coronal observations, the intermediate maximum at 19 days might be accounted for by discovery of a tendency for coronal maxima to occur on the sun approximately 180 degrees apart in solar longitude. Such a situation exists in the coronal configurations, and is sufficient to account for the intermediate peak in the graph.

By virtue of the close correlation of magnetic disturbances with disturbances of the radio-reflecting layers of the ionosphere this four-day relationship is highly significant in the prediction of the expected quality of radio communications. Detailed predictions of ionospheric conditions were prepared throughout World War II by the joint effort of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and the Interservice Radio Propagation Laboratory of the National Bureau of Standards, with the assistance not only of the Climax solar observations, but also solar data from the U. S. Naval Observatory, the McMath-Hulbert Observatory, Mount Wilson Observatory, and a large number of amateur sunspot observers.

Throughout the war the Climax coronal observations were measured even before the spectrograph plates were washed or dried, and the results were coded for immediate wire transmission to Washington and to England. The Climax data contributed primarily in the short-term forecasts of severe communications disruptions.

The four-day correlation was discovered in observational data obtained near the end of a cycle of solar activity that actually terminated at the end of 1943. The correlation has been of lower validity in the first few years of the new 11-year sunspot cycle which is now well established. The reason for this is not known.

Many interesting and unexplained tendencies of solar phenomena, originally discovered for the sunspots, also show up in the corona and prominences. For example, at the end of 1943, upon termination of a complete cycle of solar activity, the regions of intense coronal emission changed from equatorial to higher latitude concentrations. Although the tests are not sufficiently sensitive to give strong verification, preliminary investigations also give some indication that the corona possesses a shorter period of rotation in the equatorial regions than at higher latitudes, as we have known to be true for sunspots.

The operation of the Climax installation has recently been taken over by the newly established High Altitude Observatory of Harvard University and University of Colorado, which plans the founding of a larger scientific station at Climax devoted to the wider aims of the pursuit of all forms of research for which high altitude laboratory facilities open throughout the year will prove beneficial.

With the new equipment planned for construction at the High Altitude Observatory at Climax, we hope to be able to produce a larger body of observational material of higher precision relating to all observable phenomena of the sun and its atmosphere. In contributing to the world's store of information about this important nearby star, the sun, we hope to bring astronomers a little closer to the day when they successfully can attempt a definitive explanation of the mysterious and complicated interrelated phenomena of the sun and earth.

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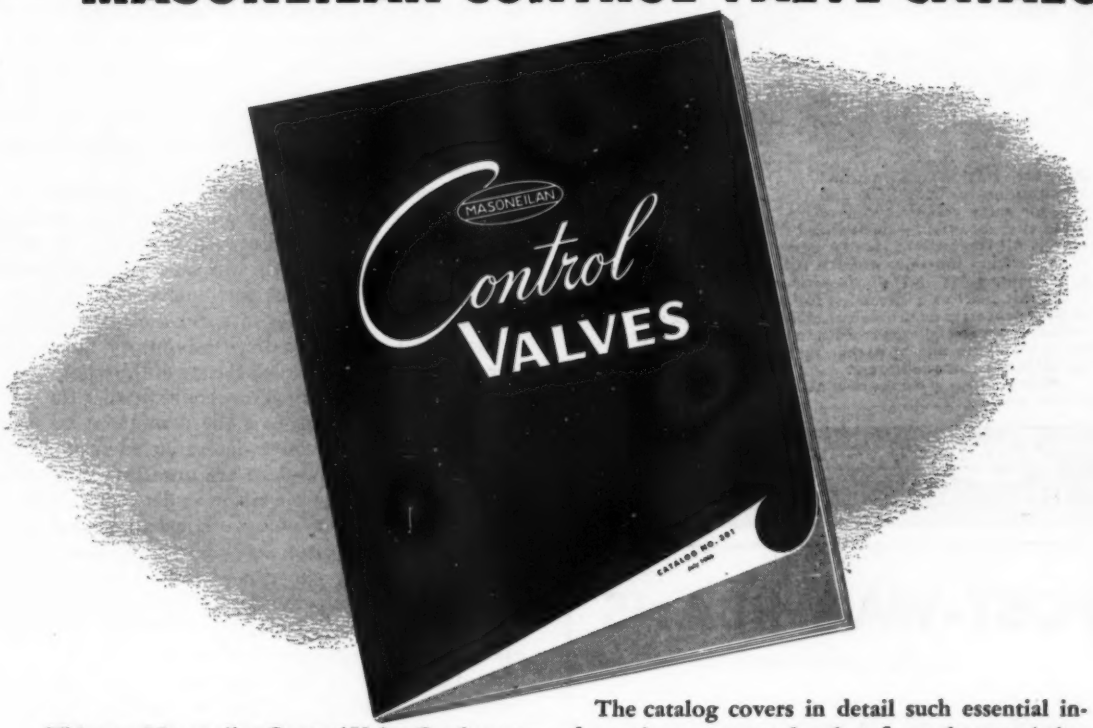

This new Masoneilan Control Valve Catalog contains complete factual information and covers every phase of control valve selection including C_v . . . Valve Flow Coefficient . . . which is a basic means for comparing flow capacities and characteristics.

The catalog covers in detail such essential information as control valve flow characteristics, flow coefficient and flow curves, materials and construction, selection of types, handwheels, dimensions, weights and other specification data. Write for your copy of this important catalog today.

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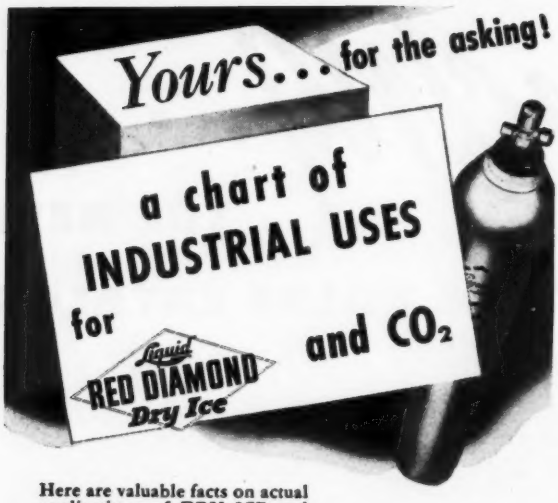

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OF MEN AND MACHINES

(*Continued from page 31*)

the details of the operation. In the aircraft *vs.* submarine case, for example, it proved advantageous to set up physiological experiments to determine the behavior of the human eye when scanning the horizon. Curiously enough, such experiments had not been done in detail before, and the work resulted in important and valuable new data concerning the use of the eye. This new knowledge could then be employed in the original problem to gain a much broader picture of the mechanism of sighting submarines from aircraft, and vice versa. Finally, when the new visual data were combined with optical measurements of the atmosphere and of properties of the ocean surface, it became possible to put together a fairly complete theory of aircraft search, by means of which one could predict what would happen in case the equipment were changed.

The scientific studies, therefore, progressed in two phases. First came the recognition of the constancy of certain quantities typical of the operation, by means of which one could predict the outcome of future operations as long as the equipment was unchanged. Finally, after analysis of the properties of various elements of the operation, and after subsidiary laboratory measurements were made, a fairly detailed theory of the whole operation was obtained, from which one could predict the outcome of future operations even if the equipment be changed. One is then in a position to determine what modifications of equipment or procedure are necessary to obtain the best results from the operation under study. Thus, by a judicious combination of a statistical analysis of the over-all results of an operation, with purely physical and physiological laboratory experiments, one arrives at a truly scientific insight into the details of the operation. When this stage has been reached, it is possible to design the operation to give the results desired.

At this stage in the investigation the worker must broaden his field of view and investigate the measures of value which must be applied to the operation. As soon as a detailed theory enables one to predict the changes in over-all results arising from changes in equipment of procedure, one must ask which result is better than the other and by how much it is better. In the case of operations of war, the measure is often easy to find: The operation is best which destroys the enemy force most rapidly or which destroys most of his productive capacity. Measures of value for peacetime operations are sometimes as easy to determine, but in many cases they are not. For instance, should an automobile traffic system be designed to transport people from the suburbs to the center of town as rapidly as possible, or to permit the delivery of the greatest amount of goods by truck, or to produce the fewest deaths? Should a housing development be designed to be most economical for the buyer, cheapest for the community to service, or most profitable for the builder?

Final decisions on alternative measures of value must be decided by the administrator; but the operations analyst can investigate the various possibilities and report on the quantitative implications of each. In any administrative decision there enter a great number of considerations which cannot be put into quantitative form. Knowledge of these qualitative aspects and ability to handle

(*Concluded on page 60*)

Investment Consultation Service

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LOS ANGELES **SAN FRANCISCO**

OF MEN AND MACHINES

(*Concluded from page 58*)

them are the proper functions of the administrator and are not the prerogatives of operations research. Unless he is to operate in a dual role of scientist and administrator, the operations research worker must work out those aspects of the problem which are amenable to quantitative analysis and report his findings to the administrator. The latter must combine them with the qualitative aspects mentioned above, to form a basis for the final decision.

Partnership for Progress

It is possible to set up similar partnerships between government or industrial administrators and operations analysts. In fact, it has already occurred in a few cases. Once the partnership is established there is no reason why operations research should not be as fruitful in aiding in the solution of peacetime problems as it was in helping solve military problems. As with problems of war, some operations will be much more fruitful to study than others. Traffic problems, for instance, are highly amenable, for data are easy to obtain, and changes in conditions (if not too drastic) can be produced to study the effects.

On the other hand, the design of city housing and facilities requires data which are difficult to obtain, the solution is strongly dependent on terrain and other individual circumstances, and operational experiments are difficult if not impossible. Research in telephone operation is not difficult because the whole system is under a more or less unified control. (In fact, operations research in this field has been going on for a number of years under the name of systems engineering.) Operations research in the heating of houses, however, might well be fruitless, because the fragmented nature of the industry makes difficult the gathering of data and makes well-nigh impossible any action on proposed solutions. Still the answers to such questions as to the best method of heating homes have their value to military as well as to civilian needs. If another war is likely to occur it would be desirable to know whether to encourage coal, oil, or electric heating in the homes in northeastern United States. Research on highway traffic might well result in suggestions for change in the design of automobiles, but the competitive nature of this industry might make it extremely difficult for the suggestions to be put into practice. It does not necessarily follow, however, that difficulty of effecting the recommendations of operations research is a valid reason for failure to apply scientific study to important problems of society.

In England a number of the scientists prominent in operations research have recently been named as scientific advisers to various ministries in the British government. It is their duty to study the quantitative aspects of housing, communications, mining, and other technological and industrial processes in an effort to achieve a degree of social well-being not heretofore attained. Similar utilization of operations analysts in this country, as partners to municipal, federal, or industrial administrators, might bring results of far-reaching importance. Certainly wartime experiences give every expectation that peacetime extension of operations analysis will make its fair contribution toward the better, more rational, life which is so universally desired.

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1936

1940

1944

1946

Can you guess the rest of the pictures?

1950

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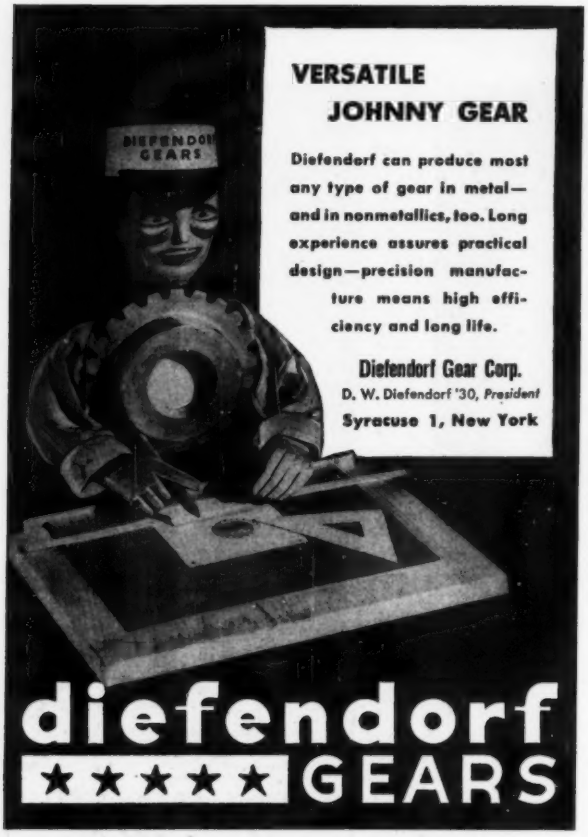
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MINORITY REPORT

(*Concluded from page 32*)

in some of this powder which he had made for medicinal uses, he apply'd it first in an iron barrel, and soon afterwards to the military art, and taught it to the Venetians. The effect is, that the art of war has since that time turned entirely on this one chemical invention, so that the feeble boy may now kill the stoutest hero. Nor is there anything, how vast and solid soever, can withstand it. . . . God grant that mortal men may not be so ingenious at their own cost, as to pervert a profitable science any longer to such horrible uses.

Death is death, defeat is defeat, and victory is victory by whatever means attained. They are no more sure and no more final if they are produced by an atomic bomb than if they are produced by black powder, by TNT, or by primitive tooth and nail. It is time to set aside our almost superstitious terror of the atomic bomb, to discount the pride of those who have made it and now gloat over the possession of its secret. It is time to evaluate it realistically. It is time to focus our attention on the problem, scarcely more urgent now than before, but certainly more clearly illuminated by the ineffable effulgence of the atomic bomb than by the flickering fires of the Byzantines. It is time to learn to live in peace with our neighbors.

A large part of Tokyo had been destroyed by fire, Japan was defeated and had already commenced overtures toward peace when atomic bombs were dropped on Nagasaki and Hiroshima. Under such circumstances the use of the atomic bomb was like kicking a man who was down, slapping a prisoner already shackled, a needless display of bravado. Without pursuing the ethical aspects of the matter, it was needless for victory. Japan was already defeated without the atomic bomb. Large parts of London, Berlin, and Warsaw were destroyed without it. Germany was defeated without it. And without the atomic bomb, in 1942 and 1943, Germany had conquered nearly all of Europe except Sweden and Switzerland, closed the universities and destroyed many libraries, made slaves of the people, reserved certain chosen specimens for breeding purposes, and commenced systematic extermination of others who were considered undesirable. All this without the atomic bomb. It is evident that the atomic bomb, if used, could not have done any greater injury to European civilization, as it is also evident that it was not the atomic bomb which finally averted its destruction. Some means must be found to prevent such atrocities from occurring again. And the means for this is not the atomic bomb.

Let us be realistic. The atomic bomb will win battles (so will intelligence), but it alone will not win wars. It will not win wisdom, nor peace, nor love of our neighbors. The control and regulation of it will yield no more important results than the control of black powder. It is not atomic energy, but the spirit of man, which must be rectified. Let us see the issue clearly, unblinded by the radiance of the chain reaction. We must find workable plans for procuring a permanent peace.

To a woman with an investment problem

There is no question about the ability of modern women to understand financial affairs quite as well as men. But the woman who manages her own investments faces a special problem in the constant advice that comes to her from well-meaning friends and relatives. As one woman wrote recently:

> "This 'piecemeal' advice only confuses me. Some of it is contradictory. How can I be sure that my present securities are the best I could own? If they are good investments today, will they be just as good tomorrow? Where can I find reliable answers to *all* my questions?"

The fact is that a sound investment program cannot be built on haphazard advice. It should be based on a thorough study of the individual's resources and needs. The choice of investments should then be made by specialists who are guided by the findings of a balanced staff of experienced investment analysts.

Old Colony Trust Company has such a staff. We have many women customers whose investment problems are now our responsibility. They receive the care and attention which an organization of specialists is best qualified to give, and which is vital to sound investment today.

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THE WRECK OF MATTER

(*Continued from page 28*)

appropriate time is well within the capacity of modern technology.

That is easy enough but how will the scholar know what to ask for? This is a knotty problem but its solution is not outside of possibility. To solve it requires in the first instance a complete coding of what is in all the stored works and a duplication of this code in every scholarly library or center of scholarship. Here all the coded references will be screened for the scholar, along lines he has predetermined, by rapid selector devices capable of scanning thousands of references per minute. Provided with a quantity of references (of which a good many may still represent false trails) and without destroying the utility of the system, the scholar will then read on these card clues, abstracts and critical comment which give him a hint as to whether he wants to see the source. When he does, the proper punching of buttons will put into action the televising process previously described. Such a system will in no way prevent photo-reproduction of source material where the scholar prefers such examination to that made possible by a television screen. Such a system can be operated as a co-operative venture of many large libraries without the alienation of titles needed for the national center, albeit with somewhat more confusion, and considerably more cost. It cannot operate in a system which circulates library material for it is critical that all the source material shall be immediately available for televising to any scholar anywhere.

It can be argued that the annual budgets of most libraries — if diverted from acquiring, maintaining, cataloguing

(*Continued on page 65*)

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THE WRECK OF MATTER

(*Continued from page 64*)

ing, storing, circulating, and keeping track of 1,000,000 or more books — could easily encompass the purchase and maintenance of the new library machinery and in addition leave something over for research. Each library would, of course, retain a collection of the most important works at such a scale (say the 200,000 volumes of the new undergraduate library of Harvard) that not all readers would be condemned to the mechanistic process which would be reserved largely for the convenience of the scholar. Each library would also maintain a certain amount of current and not as yet coded material to be discarded when the coding was completed.

Coding Human Learning

The crux of such a system would, of course, lie in the coding. For the billions of words already written and stored only a slow progress might be possible. It is possible to install a coding process for everything published after a given day and, in a not too distant future. This would comprise a coding of a large part of the past literature.

But, even then, the job of coding, the intellectual skill required, the time consumed, the self-sacrifice required of the coders is almost inestimable. These coders would have to possess the best minds; they could not be mere clerks. To get all these best minds to contribute the codification of even a few volumes a year per man would require a co-operation never yet approached by the company of scholars. The scholar is at least as selfish as the ordinary man; probably he is more so. Unless the scholars as a body would enter into such a project it would be predoomed to failure; it might fail even if they did join such a crusade.

Against such a pooling of resources and talents would be raised the ambitions of librarians asked to give up their treasures which are sometimes the only way the importance of their libraries can be measured. Against such a program would be raised the pride of trustees, college presidents, collectors of rare and even of uncut books, donors of oak and marble, and most of all the pride of the Alumni. There would be fear of over-centralization, fear of mechanism. Finally we might expect the apathy of scholars presented to a proposal which called upon each to do a volume of work for the good of all which would in no way enhance his individual prestige. How far away do all these imaginable adverse forces place the library millennium?

I put this question with no tongue in cheek. At this very moment I have the task of planning for a new library building in our own institution. Shall this library building be less forward looking than the apparatus for testing the flight characteristics of planes, for measuring radioactivity, for exploring the nucleus? Shall it fail to take advantage of the knowledge in our own institution of rapid selectors, radio, and television? What are we to do?

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(*Continued on page 66*)

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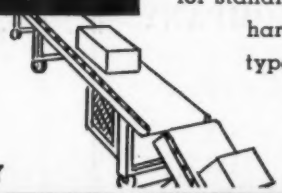

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THE WRECK OF MATTER

(*Continued from page 65*)

has now in hand about $2,500,000 with which it must construct the Charles Hayden Memorial Library as soon as governmental permits can be obtained. This means that the planners of this new building cannot postpone their planning long enough to learn whether any of the conjectures previously made have likelihood of soon attaining reality. No one in his senses would dare build a building today founded in the assumption that they would, and that all previous library thinking could, therefore, be discarded.

The building has to serve four functions: it must offer *a* tool for the undergraduate and the scholar in science and engineering; it must offer *the* tools for the student of social science and the humanities; it must offer extra-curricular fare in non-scientific fields to whet the undergraduate appetite; and it must apply our forces to new methods of librarianship through research. Each of these requires a somewhat different building.

On the one hand, for the student of science, the building is to offer the management for the scholarly branch libraries in the several disciplines which, in the present state of librarianship, are most conveniently located near to the practitioners of the disciplines. It must serve as central repository for older, and for fringe, material; it must supply a broader base of reference than can practically be furnished in the branches; it must take care of the underclassman so that the advanced libraries can be relieved of him to the benefit of all concerned. It must be ready to assume a still larger role should mechanism become important in librarianship; for when and if it does, centralization will clearly be indicated.

For the student of the humanities the library must make quite a different provision. For him the library is, in literal truth, the laboratory. Accordingly it is desirable that faculty, seminar, and conference room, and library materials all be in the same area — indeed in the same building. This requires an arrangement quite different from that of branch library, laboratory, and class room in the technological departments.

In an institution such as Technology the curricular time available for study of the humanistic subjects is inevitably short — too short perhaps — to produce a well-rounded man. There rests a further responsibility then to provide stimulus to the underclassman and the senior — to compete if you will with the laboratory for his spare time by feeding him with at least the *hors d'oeuvre* which may stimulate an appetite on his part for further tasting of other

(*Continued on page 68*)

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THE WRECK OF MATTER

(*Continued from page 66*)

types of man's thought. A large part of this responsibility devolves upon the new library.

Mechanistic Diffusion of Knowledge

Finally, research must incessantly be carried on, with the special tools at Technology's disposal, to help in the determination as to how far the world can go along lines indicated in the previous text. To accomplish this the library must not only take account of possibilities in codes, selectors, television, and microphotography but also of developments in visual and aural aids to learning. Specifically, laboratories are required in which methods may be tested on both the mechanical and intellectual scales; future staff members must be selected who will be able to contribute to such achievements, be temperamentally anxious to contribute, and be desirous of seeing the possibilities and not the difficulties.

In time any one of these present purposes may become archaic; scientific literature may be organized quite differently, teaching in the humanities may become divorced from the library, extra-curricular stimuli may be provided by other means or may even become unnecessary, research may reach the end of any profitable road. Accordingly no building can be profitably contrived which will freeze any one of these activities either in form or in scale.

To resolve this dilemma will not be easy of course. We shall make our building of equal story heights and of such floor structure that every area can accommodate the full weight of books as now stacked or, equally, will provide reading space, teaching space, laboratory space, or viewing screens and rapid selectors. This building will have almost no impedimenta to the use of space and this is its principal characteristic.

There has to be, of course, a first program for the use of space. The mechanical equipment and the laboratory are to be housed in a half basement. The first floor takes advantage of the building's handsome site on the Charles River (between the main building of M.I.T. and Walker Memorial) and provides an "Avenue of Culture" along which the student will naturally pass in going from the educational area to the recreational area. On this avenue will be an exhibition gallery, the distinguished Dard Hunter Paper Museum, an undergraduate reading room, the recreational reading collection, and the libraries of English and History. No effort will be spared to make this the most attractive place physically in the entire Institute. It is hoped that the intellectual attraction will be no less apparent.

The second floor, which is not on a through passage, will house both library administration and the scholarly over-all reference collections and source material for all disciplines plus the special serious collections in economics and social sciences which pass under the name of the Dewey Library. The third floor will house the humanities faculties (and also their seminars) and a substantial audio-visual center embracing the most contemporary applications to education of the arts of recorded sound and light.

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(*Concluded on page 70*)

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THE WRECK OF MATTER

(*Concluded from page 68*)

tion may to accelerate progress toward a more efficient librarianship. But the space vehicle of librarianship which might carry us some day to the absorbing visible planets, still so tantalizingly out of reach, will not be the product of a single institution. It will require a very large movement of scholars, of librarians, of financial sponsors, and perhaps of government before anything of serious import may ensue. Still the problem is real enough; Anatole France's fancy, Rider's extrapolations, Hardin's Gordian-knot-cutting may none be idle prophecy unless the more imaginative Bush proposal is grappled with tenaciously. The grappling must be without cynicism or selfishness and must be performed simultaneously by very many more people than can be found on our acreage on the Charles River.

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THE TABULAR VIEW

(*Concluded from page 10*)

Widespread Knowledge of the elements of nutrition and sanitation might have reduced the casualties among native and American defenders of Bataan is the opinion (page 22) of SAMUEL A. GOLDBLITH, '40, whose experiences as a prisoner of war at Camps O'Donnel and Cabanatuan enable him to speak with vivid first-hand knowledge. Mr. Goldblith is now research assistant in the Institute's Department of Food Technology and is studying for an advanced degree.

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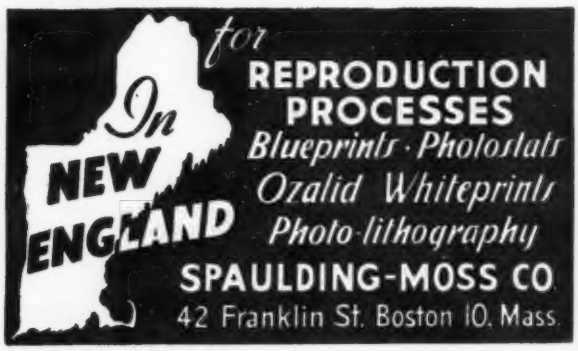

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FRANK C. BALKE '14, Balke and Krauss Company, 427 West Market Street, Indianapolis

KANSAS
FRED C. KOCH '22, Winkler-Koch Engineering Co., 335 West Lewis Street, Wichita

KENTUCKY
TINSLEY W. RUCKER III '31, The Crescent Panel Company, 32d and Market Streets, Louisville 12

LOUISIANA
THEODORE O. HOTARD '12, 221 Pelican Avenue, New Orleans 14

MAINE
FRANK A. KNIGHT '38, Eastern Corporation, Bangor
LEWIS D. NISBET '09, 44 Montrose Avenue, Portland

MARYLAND
GEORGE W. SPAULDING '21, 1605 Lexington Building, Baltimore 1

MASSACHUSETTS
ROBERT F. BURNETT '10, 85 North Main Street, Fall River
A. RUSSELL PIERCE, JR. '31, Palmer Scott Boatyard, New Bedford
LYNN WETHERILL '25, High Voltage Bushing Engineering Division, General Electric Company, 100 Woodlawn Avenue, Pittsfield
ALBERT D. KING '32, De Bell and Richardson, 3 Post Office Alley, Springfield

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ADAM K. STRICKER '29, 1227 Bishop Road, Grosse Point Park, Detroit

MINNESOTA
LELAND CLAPPER '09, 5600 London Road, Duluth
CHARLES W. DREW '19, Minneapolis-Honeywell Regulator Company, Minneapolis

MISSOURI
HARRY L. HAVENS '09, Havens Structural Steel Company, 1713 Crystal, Kansas City
WESLEY W. WEDEMEYER '30, Wedemeyer and Hecker, Architects, 319 North Fourth Street, St. Louis 2

MONTANA
WALTER R. C. RUSSERT '18, Anaconda Copper Company, Butte

NEBRASKA
JOHN M. HANLEY '30, Northern Natural Gas Company, Aquila Court Building, Omaha

NEW HAMPSHIRE
BLAYLOCK ATHERTON '24, 142 Main Street, Nashua

NEW JERSEY
GEORGE A. CHUTTER '21, 109 Central Avenue, Glen Rock (Newark area)

NEW YORK
ANDREW F. ALLEN '12, State Department of Health, Albany
THOMAS H. SPELLER '29, General Engineering Company, 785 Hertel Avenue, Buffalo 7
JOHN C. FRUIT '02, Equitable Life Assurance Society of U. S., 393 7th Avenue, New York 1
RAYMOND G. BROWN '16, Comstock and Westcott Inc., Niagara Falls
C. KING CROFTON '22, 1132 Lincoln-Alliance Bank Building, Rochester 4
A. J. TACY '27, Room 645, Building No. 2, General Electric Company, Schenectady
J. MURRAY HASTINGS '13, 606 Hills Building, Syracuse

OHIO
JAMES B. HOLDEN '30, 276 Sundale Road, Akron
KENNETH A. WRIGHT '19, Johnson Service Company, 1905 Dunlap Street, Cincinnati 14
CHARLES B. ROWLEY '12, Charles Bacon Rowley and Associates, Keith Building, Cleveland
JAMES H. BLODGETT '20, Superintendent, Division of Sewage Treatment, Columbus
EUGENE HERZOG '27, 26 Cliff Street, Dayton
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PERCY TILLSON '06, 3003 North Front Street, Harrisburg
EDWARD J. HEALY '23, Philadelphia Brewing Company, 6th and Clearfield Streets, Philadelphia 33
HAROLD L. LANG '09, Carnegie Institute of Technology, Pittsburgh 13
G. C. WILSON '15, 907 East King Street, Lancaster
LOUIS MORSE '96, York Corporation, Roosevelt Avenue, York

RHODE ISLAND
DONALD G. ROBBINS '07, c/o International Braid Company, 47 Charles Street, Providence

TENNESSEE
DANA M. WOOD '06, 619 Union Building, TVA, Knoxville
DONALD W. SOUTHGATE '11, Nashville Trust Building, Nashville 3

TEXAS
JONATHAN A. NOYES '12, 1914 Commerce Street, Dallas 1
JOSEPH H. McEVOY '21, 202 McGowen Avenue, Houston 6

UTAH
GEORGE M. GADSBY '09, Utah Power and Light, Kearns Building, Salt Lake City

VIRGINIA
DONALD N. FRAZIER '11, 1226 Mutual Building, Richmond

WASHINGTON
HOLLAND H. HOUSTON '24, 215 Fifth Street, Olympia (Seattle area)
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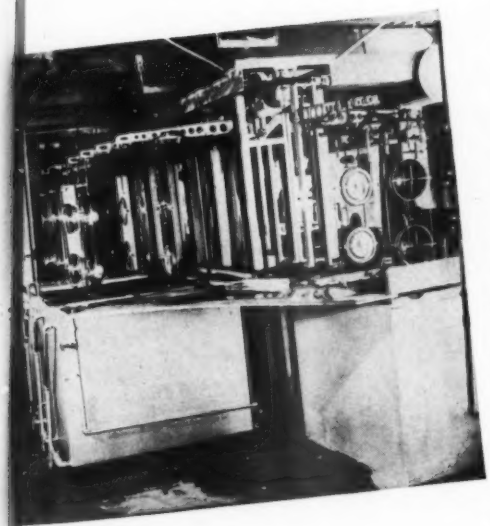

Shown here are two 15,000-gallon rubber-lined barge tanks. 10 ft. in diameter x 27 ft. long. Weight 27,000 lbs. each. Rubber-lined by Manhattan with acid-proof rubber for conveying sulphuric acid solution.

Tanks like these are easily handled in Manhattan's giant tank-lining vulcanizer, which is 15 ft. in diameter and takes anything that can be shipped on a railroad flat car.

Below is an installation consisting of a number of rubber-lined plating, acid dip and rinse tanks lined by Manhattan for use with a Hanson-Van Winkle-Munning elevator-type, full-automatic conveyor.

Manhattan has developed a special rubber-to-metal bond that cannot be mechanically separated. Regardless of contraction and expansion of metal under radical temperature changes, Manhattan's rubber lining compound clings securely, does not crack or oxidize.

Manhattan rubber linings resist abrasion and shock and eliminate stray currents. They pay for themselves many times over in savings on maintenance. A textile finishing plant reports over 25 years constant service in a battery of 10 one-thousand gallon chemical storage tanks which are still giving satisfactory service.

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RAYBESTOS-MANHATTAN, INC.

MANHATTAN RUBBER DIVISION

EXECUTIVE OFFICES AND FACTORIES — PASSAIC, NEW JERSEY

ANOTHER NEW VARIAC

FOR some time there has been a steady demand for an intermediate size VARIAC . . . something between the new Type V-5 (old Type 200-C) with a 5 ampere rated output, and the Type 100 rated at 18 amperes. The new Type V-10 has been designed to supply this need. Its rated output is 10 amperes, with a maximum of 15. This maximum rating coincides with the capacity of outlets, plugs, cords and No. 14 circuits ordinarily found in the laboratory and in the home.

The electrical and mechanical features . . . many of them exclusively found in the VARIAC, and all of them entirely new in the "V" types of VARIAC . . . are similar to those in the Type V-5, and include: —

1. New Unit Brush — brush, holder, pressure spring and current lead in one unit; removable in a second without any tools; when brush wears away, holder cannot short-circuit winding
2. Improved terminal plate with molded barriers between terminals to prevent short-circuits from strands of wire; both screw- and solder-type terminals; wiring diagram on terminal plate shows normal voltage between terminals
3. New strip-wound, silicon-steel core contributes to increased efficiency and to weight reduction of 25% below normal
4. Entirely new mechanical design of structural parts, mostly in aluminum
5. Double-pole line switch breaks both sides of the line
6. New, large output-voltage dial with additional calibration points and larger figures
7. A single screw, readily accessible under dial, loosens shaft for reversing dial and knob to change from table to panel mounting without affecting brush or stop settings

The Type V-10 VARIAC will be in production soon; deliveries are scheduled from November. Prices of the six models of the Type V-10 range between $27.50 and $35.50.

Write for a copy of the new VARIAC BULLETIN. It describes the Type V-10 and all other VARIACS.

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